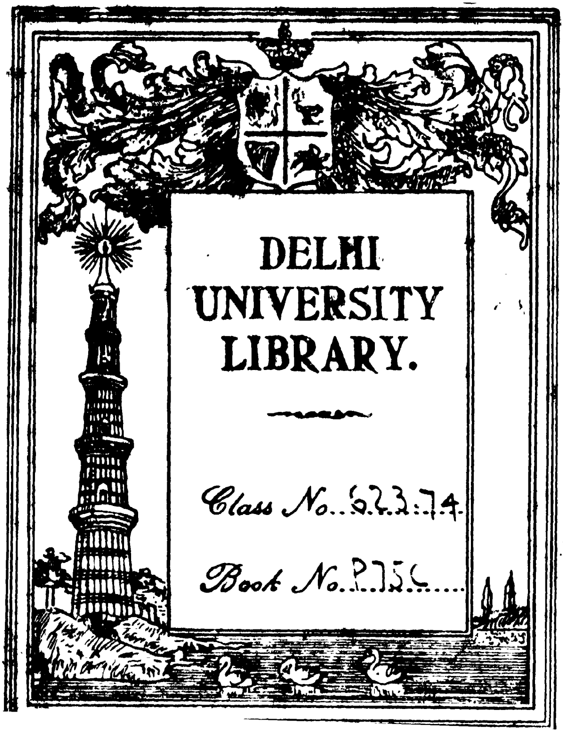

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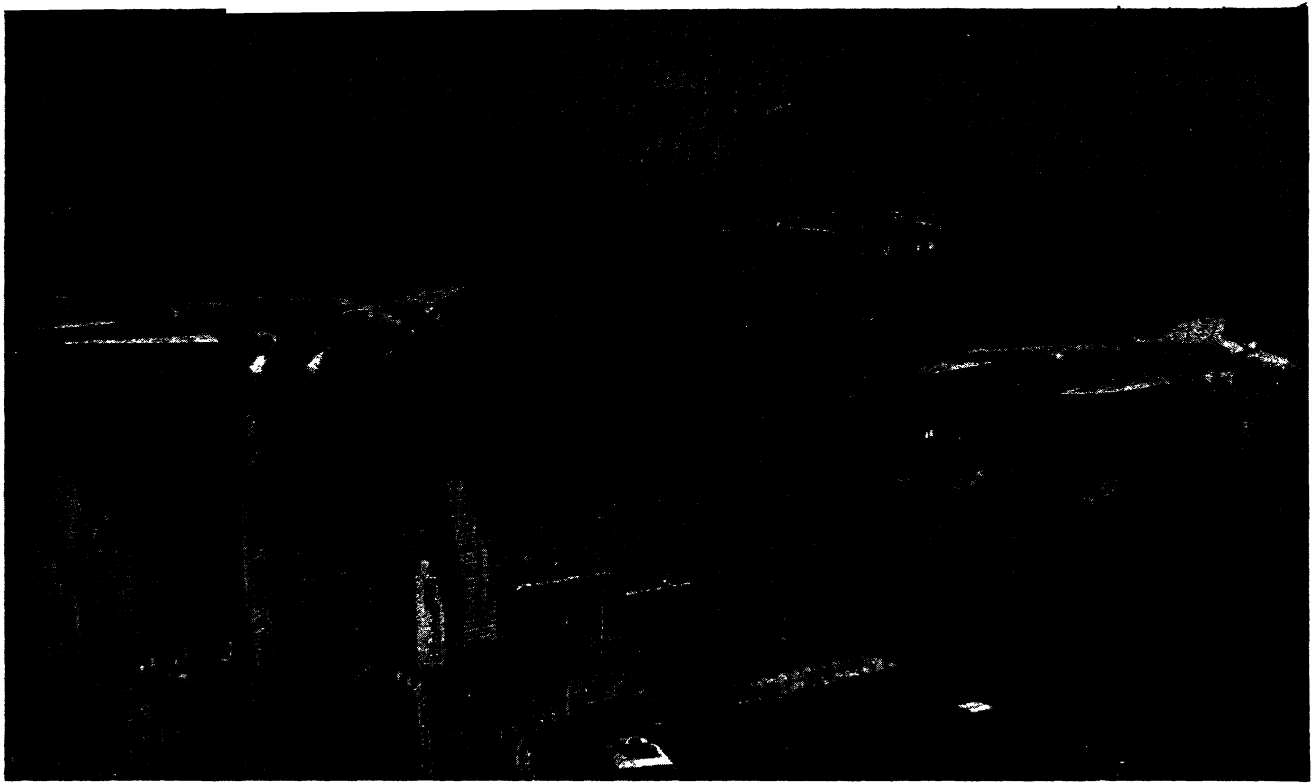

Flight of bombers over New York City.

Civil Air Defense

A Treatise on the Protection of the Civil Population against Air Attack

by

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To the rising generation of America
who must solve the problem
of the air menace

PREFACE

Recent developments in Europe and the rapidly increasing radius of action of long range bombardment aviation bring the problem of defense against air attack to the doorstep of every country in the world. No longer may historic ocean barriers be considered a sufficient safeguard against this world-wide menace, and it is therefore incumbent upon every government to come to grips with this problem in all of its many ramifications.

It is not our purpose here to discuss the ways and means by which the United States might be invaded from the air by foreign powers or even to consider the probability of such invasions in the future. These questions are altogether outside the scope and purpose of this book. It is sufficient for our purpose merely to recognize the danger of air attack and to point out the necessity of every country's putting its national house in order to meet such an eventuality, much for the same reason that we recognize the ever-present possibility of fire and take precautions to guard against its occurrence and to limit its damage.

With regard to the question of defense against air attack, there are two general attitudes, either of which may be injurious to a country's national security. On the one hand, those responsible may magnify the difficulties of foreign invasion from the air and so minimize the sense of danger in their own minds as to feel that there is no need to prepare for such a seemingly remote eventuality. This is very much the attitude of the ostrich who sticks his head in the sand and feels secure because he cannot see his approaching enemy. On the other hand, they may so magnify the threat of air attacks as to lose all sense of reality and thus engender in the public mind an exaggerated feeling of alarm which may easily lead to widespread confusion and panic. Neither of these extremes is justifiable or to the best interests of a country's national security. The safest course is to face the question of air attack rationally and realistically and to take such measures of defense as are reasonably required to meet the situation when and if it should eventuate.

In view of recent war experience in Europe and the Far East, it seems highly desirable that the public know the present and probable future capabilities and limitations of air power and be fully informed as to the best ways and means of countering this threat. It is also important that all echelons of government should clearly understand the nature of this problem, what they can and should do so as best to defend their country, and particularly how to protect their cities and urban population against foreign air aggression if the country is ever so unfortunate as to be subjected to this most destructive form of warfare.

The purpose of this book is critically to examine and analyze the powers and limitations of modern air power and to discuss the various defensive measures that should be taken to cope with this danger, to the end that our country, and particularly our civil population, may be prepared to meet this perilous situation should it ever arise.

The appearance of this volume should be taken, not as an acceptance of the inevitability of war, but rather as a means for bringing to the public notice a problem of outstanding importance to every country in the world today.

The methods of protection against air attack described in this volume are based upon the best modern practice in Europe, and the author is indebted for much of his knowledge to official publications of the leading European governments and to works of private authors in this field. Special acknowledgment is made, in the "List of Illustrations" and in the reference notes, of the use of certain information and illustrations appearing in official British Government publications on Air Raid Precautions and Civil Air Defense, for which permission was kindly granted the author by the Controller of His Britannic Majesty's Stationery Office. The author's thanks are also due to the Chema Mfg. Co., Bush House, London, WC2, for the use of certain illustrations of this company's civil air defense equipment.

The author hopes that the information set forth herein will prove of interest to all those who have concern for national and local security in time of war and to the humble householder who from time immemorial has been the ultimate defender of his hearth and home.

AUGUSTIN M. PRENTISS.

CHICAGO, ILL.

CONTENTS

PAGE

Preface ix

Illustrations xiii

Abbreviations. xv

Introduction 1

CHAPTER I

Rise of Air Power since the World War. 9

CHAPTER II

Means and Effects of Air Attack. 20

CHAPTER III

Defense against Air Attack. 69

CHAPTER IV

Protection against High Explosive Bombs. 77

CHAPTER V

Protection against Incendiary Bombs. 114

CHAPTER VI

Protection against Gas 127

CHAPTER VII

Aircraft Warning Service. 164

CHAPTER VIII

Air Raid Warden Service. 174

CHAPTER IX

First Aid and Medical Service. 189

CHAPTER X

Fire Precautions Service 199

Page

CHAPTER XI

Rescue and Debris Clearance Service 211

CHAPTER XII

Demolition and Repair Service 217

CHAPTER XIII

Decontamination Service 222

CHAPTER XIV

Air Raid Precautions Command Organization 235

CHAPTER XV

Training of Air Raid Precautions Personnel 249

CHAPTER XVI

Protection of Industrial Establishments 259

CHAPTER XVII

Protection of the Home 279

CHAPTER XVIII

Other Measures of Civil Air Defense 290

Appendix 305

Bibliography 313

Index 327

ILLUSTRATIONS

Flight of Bombers over New York City . . . . . *Frontispiece*

FIGURE PAGE

1. *Bomb Trajectories* 21
2. *Demolition Bomb* (2,000 *Lb.*) 24
3. *General Purpose Bomb* (300 *lb.*) 25
4. *Fragmentation Bomb* 26
5. *Various Sized Bombs* 28
6. *Bomb Penetrations* 31
7. *Effect of Crater*. 37
8. *Typical Bomb Crater* 38
9. *Bomb Crater* (300 *lb. Bomb*) 40
10. *Craters of Demolition Bombs*. 41
11*. *Radius and Depth of Destruction* 43
12. *Damage to Houses by* 600 *lb. Bomb* 45
13*. *Incendiary Bomb*. 54
14. *Danger Areas of Bombs* 63
15. *Dugout Shelters* 93
16. *Section of Covered Trench* 99
17. *Open Trench Shelters* 100
18*. *Domestic Surface Shelter*. 107
19*. *Sandbag Barricade* 109
20*. *Civilian Gas Mask* 137
21*. *Civilian Mask Canister* 138

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FIGURE PAGE
22. *Gas Mask for Infants* 139
23*. *Civilian Duty Mask* 140
24*. *General Service Mask* 141
25*. *Heavy Anti-gas Suit* 145
26. *Gas-tight Refuge Room* 150
27*. *Blanket Air Lock* 152
28*. *Gas-tight Blanket Door* 153
29. *Collective Protector* 155
30. *Mobile Decontaminator* 159
31. *Diagram of Aircraft Warning Service* 167
32. *Diagram of Warden Districts* 179
33. *Diagram of Warden Organization* 181
34*. *Small First Aid Post* 194
35*. *Central Decontamination Depot* 224
36*. *Gas Cleansing Center* 228
37. *Organization Chart, A.R.P.D* 238
38. *Scheme of Organization, A.R.P.D* 241
39. *Factory ARP Organization* 264
40*. *Shelter under Factory Building* 270
41*. *Plans of Refuge Rooms* 284
42. *Municipal Organization for Civil Air Defense* 300

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ABBREVIATIONS

ARP	Air Raid Precautions
ARPD	Air Raid Precautions Department
C	centigrade
cu.	cubic
cu. ft.	cubic feet
cu. in.	cubic inches
deg.	degrees (angular)
°	degrees of temperature
F	Fahrenheit
ft.	feet
ft./sec.	feet per second
gal.	gallons
gal./min.	gallons per minute
GIO	Gas Identification Officer
H.E.	high explosive
hr.	hours
in.	inches
kg.	kilograms
l.	liters
lb.	pounds
lb./sq. in.	pounds per square inch
min.	minutes (of time)
mg.	milligrams
oz.	ounces
m.p.h.	miles per hour
sec.	seconds (of time)
sq.	square
sq. ft.	square feet
sq. in.	square inches
yd.	yards

CIVIL AIR DEFENSE

INTRODUCTION

Before the advent of air power, wars were fought in two dimensions, *i.e.*, on the surface of the land and water. In order, therefore, for an invading force to destroy the cities in the hinterland of an invaded country, it was necessary that it first break through the frontier defenses of that country and gradually push back the defending forces until the enemy's cities were at least within range of the invader's artillery. This meant that, except in the immediate vicinity of the battle front, the civil population of a belligerent country was safe from the dangers of war, until its army and navy were virtually defeated.

With the appearance of the airplane as an instrument of war, all this was changed almost overnight. For the airplane at once carried warfare into three dimensions, and battles were no longer limited to the earth's surface. With the recent vast increase in the range and striking power of aircraft, the air arm has become almost universal in action, since it not only can act against the hostile land and sea forces but can also overleap entrenched armies and embattled fleets and strike directly against the enemy's cities and other vital areas far behind the battle front. Moreover, since the space in which airplanes operate is so vast, the power of the offense is immeasurably greater than that of the defense, and it is practically impossible to prevent a determined air attack from being pushed home, owing to the difficulty in finding and intercepting hostile bombers before they reach their objective. For these reasons, many military authorities hold that, with a decided air superiority, air attack alone can compel a hostile state to surrender by bringing such an overwhelming pressure against its civil population that public opinion will compel the Government to sue for peace. This is the radical air power viewpoint, first proposed by the Italian Chief of Air Corps, General Douhet; it is opposed by the conservative military school of thought, which asserts that, notwithstanding the enormous destructive powers of modern aircraft, decisions in war will still be reached upon the field of battle and that the only way to defeat an adversary is to overcome his armies in the field.

Although it may be doubted whether direct air action against an enemy's civil communities will alone be sufficient to win a war, it is generally agreed among competent military authorities that air power is one of the most important factors in modern war. The majority of military writers also agree that no amount of active air defense can prevent a determined enemy from carrying out devastating air attacks on the home territory of an opponent, if the aggressor has a sufficiently powerful air force and is willing to accept the losses that a well-organized opponent can inflict. This being the case, it is apparent that, even if air forces cannot win wars without the aid of armies and navies, this limitation does not in any degree lessen the seriousness of its threat against the civil population.

It is further apparent that, even if both sides at war confine their attacks to legitimate military objectives, there is little safety for the noncombatant civil population, because of the impossibility of damaging military objectives in civil communities without great injury to the surrounding population as well. Thus, it is obvious that an aviator, flying at night at a high altitude over a darkened city, cannot with certainty identify objects and persons he is permitted to bomb. As Prof. James W. Garner* so aptly points out:

> How can he distinguish between military forces and the civil population; between military works, depots and factories engaged in the manufacture of arms and munitions or used for military purposes, and other establishments engaged in the manufacture or production of articles used for civil purposes; or between railway lines used for military purpose and those which are not? To require aviators to single out one class of persons and things from the other and to confine their attacks "exclusively" to *one* of them will in many cases be tantamount to an absolute prohibition of all bombardment.

It, therefore, becomes a matter of utmost importance to the future of civilization critically to examine and evaluate the various weapons that may be employed by the air force of a modern state at war and to weigh the various factors concerned in the employment of each. We may thus arrive at some rational estimate of the weapons most likely to be used by an enemy, scrupulous or otherwise, and the best means of defense against such weapons.

---

* "Proposed Rules for the Regulation of Aerial Warfare," *American Journal of International Law*, 1924, p. 69.

In future wars, air power is destined to play a constantly increasing role. The development of bombardment aviation has already reached a point where its range and destructive power make it one of the major means of waging war. Air power may be used to supplement military and naval forces by striking directly at armies in the field and fleets in action or by operating against the enemy's munitions industry and economic system generally, with a view to undermining the foundations of his military strength. Air power may also be used to destroy the morale of a hostile state by bringing such pressure directly against the civil population that public opinion will compel the government to sue for peace.

Despite the great improvement in intercept and pursuit planes and antiaircraft artillery since the World War, the development of bombardment aviation has been even more remarkable, so that today the advantage in air warfare appears still to lie with the attacking bombers. And this is particularly true when the factors of surprise and concealment in bombing operations are considered.

Since bombers can now reach their objectives by instrument flying in almost any kind of weather, they may conceal their approach under the cover of darkness, fog, mist, clouds, and artificial smoke. Also, by the new technique of silent approach, they cannot be detected by sound locators. Bombers can also fly above and below the effective ranges of antiaircraft guns. As neither defensive air forces nor antiaircraft artillery can engage bombers unless they can see them, it is obvious that the bombers, by concealing their approach, may carry out surprise attacks without much hindrance from antiaircraft defense.

The threat of a modern air force is the destructive power of its bombardment aviation. All other forms of aircraft either are auxiliary to the employment of bombers or are for purely military purposes, which do not enter extensively into the strategic use of air forces. Hence, we may confine our consideration to the various weapons with which modern bombardment aviation is equipped.

The armament of the modern bomber comprises high explosive, incendiary, and gas bombs, chemical sprays, and machine guns and light cannon. As the last two weapons are intended primarily for defending the bomber against intercept and pursuit planes that may attack it in flight and are not extensively used against personnel on the ground, they may be dismissed from further consideration here.

Undoubtedly the greatest danger to the large cities from air attack stems from the element of surprise; for sudden, unexpected attacks will result in large numbers of people being caught in the streets and open spaces without any form of protection. With the technique of silent approach and under cover of darkness and thick weather, there appears to be little to prevent air attacks being delivered with great suddenness and surprise and with very disastrous results.

When bombs are used in such attacks, the bursting of the bombs will, of course, give belated notice that an air attack is in progress; but if spray is used, it is entirely noiseless and may fall in such fine droplets as to be altogether unnoticeable to those on whom it falls. They may thus become seriously contaminated without even being aware of it until incapacitating symptoms appear hours later. The number of casualties thus produced may conceivably reach serious proportions, although there would be but a small percentage of deaths, since mustard gas, for example, causes only about 2 per cent of deaths as against approximately 25 per cent of deaths from high explosives.

It is at this point that the belligerent's philosophy of battle enters into the picture.

In the waging of modern war, there have grown up two quite distinct schools of thought. One holds, in principle, that the ends of war justify the means and that there is no limit to the degree of force which may be employed to gain victory. The other school of thought holds that no greater degree of force is justified in war than is necessary to achieve victory in battle and that ruthless and indiscriminate destruction of life and property is not warranted in the conduct of warfare. The German military writers, for example, have long been advocates of unlimited warfare. Thus, the German War Book of 1910 sets forth this philosophy of battle as follows:

> In the matter of making an end of the enemy's forces by violence it is an incontestable and self-evident rule that the right of killing and annihilating, hostile combatants is inherent in the war power, and its organs, and that all means which modern inventions afford, including the fullest, most dangerous, and the most massive means of destruction, may be utilized.

On the other hand, our own Government has consistently held to the doctrine of restricted warfare and believes that no more force should be employed in war than is required to bring about the submission of the enemy as soon as possible. According to this view, the choice of means for waging war is not unlimited among civilized states, and the scope of armed conflict is measured by the recognized limits of military necessity.

In the World War, the armies of the belligerents were the largest ever raised and, in many cases, consisted of the entire able-bodied manhood of the nation. Also, the vast quantities of munitions required taxed the productive effort of each state as never before. The effort to maintain these large armies thus strained the economic life of many nations to the breaking point. Accordingly, many of the highest military strategists hold that measures which increase the enemy's burden of maintenance will contribute far more toward deciding the issues of future wars than the intrinsic loss of man power from battle deaths.

From World War experience, military authorities variously estimate that modern war requires three to six men behind the lines to keep one soldier at the front; moreover, the burden of maintaining an army on the field is enormously increased by the task of caring for the sick and wounded. Men put out of action by nonfatal battle wounds, are, for the duration of their hospitalization, military liabilities instead of assets. The strategic value of battle deaths has thus greatly diminished, and increasing emphasis is placed upon *nonfatal* battle casualties. Those instrumentalities which enable an army to inflict upon the enemy the maximum number of nonfatal battle casualties, in proportion to the military effort expended, may accordingly be regarded as the most effective military agents.

This being the case, if a belligerent state embraces the Douhet doctrine of direct pressure against the enemy's civil population by air action and has sufficient air power to make it really effective, it may win a quick decision in war by sudden overwhelming air gas attacks upon its opponent's cities, with far less destruction of life and property since gas is, on the whole, far less fatal to human life than high explosives and incendiaries. At the same time, because of its greater coverage and casualty-producing capacity and especially its far-reaching psychological effect upon an unprepared civil population, gas would probably be more effective in breaking a people's morale and will to war.

On the other hand, if a nation at war does not possess a large preponderance of air power, sufficient to win a quick decision before its opponent can prepare its civil population to endure and resist air attacks and to retaliate by counter air attacks, it is probable that direct air action against an opponent's civil population, alone, cannot win a war. Once the civil population of a state is prepared and trained to meet air attacks by effective organization and training and efficient active and passive defensive means, it is fairly certain that air attacks alone will never secure a decision in war. On the contrary, air attacks will serve only to steel the nerves of the civil population and increase its determination to carry on the war to a successful conclusion at all costs.

When a war has reached a stage where it can be won only by the combined power of all the nation's armed strength—army, navy, and air forces—air attacks will probably be relegated to a secondary role, supporting the principal military and naval effort and operating against military objectives in its opponent's territory. Here gas may be expected to play but a limited part behind the battle front: for gas is, on the whole, less effective against a *well-disciplined and equipped* civil population than against armies in the field where the conditions of field service are such that anti-gas protective measures cannot be so effectively and thoroughly carried out.

Also, in a war of attrition, involving the whole economic strength of a nation, incendiaries would appear to be more effective than high explosives in operations against an enemy's munition industry and his economic system generally, although both would undoubtedly be used concomitantly in many situations. Though incendiaries are more destructive of property than high explosives, they are far less destructive of human life and, like gas, if properly used against military objectives the legitimacy of their employment in war cannot be logically challenged.

Civil air defense comprises broadly two general categories of activities, collectively known as *Active* Defense and *Passive* Defense. Active Defense consists in the positive measures employed by the armed forces of the nation for actively combating enemy air attacks, such as defending air forces, antiaircraft artillery, aircraft warning service, and balloon barrages, the preparation and operation of which are a responsibility of the military authorities.

Passive Defense, on the other hand, consists in the negative measures employed by the civil authorities for the protection of the civil population, municipalities, and industrial establishments against the consequences of hostile air attack and include the following:

1. Means for organizing and training the civil population so that everyone will understand the nature and limitations of air attacks and will know what to do when such attacks occur, panic, hysteria, and confusion during air raids being thus prevented.
2. Means for warning communities of the approach of hostile aircraft so that all unprotected persons may seek shelter.
3. Provision of air raid shelters for the protection of personnel from injury by high explosive bombs, gas, and incendiaries.
4. Plans for the evacuation of women, children, and nonessential persons generally from large urban communities that are liable to air attack.
5. Means for maintaining vital public utilities and services, such as water, food, light, transport, and communications.
6. Means for protecting important public buildings and industrial establishments from damage by high explosive and incendiary bombs.
7. Means for extinction of lights (blackouts) and control of lighting.
8. Means for first aid and medical treatment of casualties.

In a word, Passive Defense includes all those measures which are necessary to

1. Minimize the consequences of hostile air attack against civil communities.
2. Prevent impairment of the national war effort through demoralization of the civil population.
3. Avoid disruption of normal civilian life.

Since, under our form of government, state and local authorities are required to furnish protection to life and property within their jurisdictions, it is the responsibility of the several states and municipalities, in the execution of their constitutional police power, to take adequate measures for the protection of their civil populations from air attack as well as other forms of attack. And so the responsibility for providing for adequate Passive Defense in each community rests upon the state and local authorities thereof.

Although the responsibility for Passive Defense devolves upon our state and local civil authorities, necessary assistance in this effort can be rendered by our national Government. Thus, the Federal Government will undoubtedly exercise general supervision over Passive Defense planning by our states and local communities; will coordinate Passive Defense measures with Active Defense measures; will prepare essential instruction material for the guidance of civil authorities; and will make personnel available in each community to advise and assist the civil authorities in the organization and preparation of the Passive Defense of the community.

Although Passive Defense cannot guarantee a nation against hostile air attacks, it can considerably mitigate their severity, as regards the civil population, and it can materially reduce damage to vital public and private property. Moreover, if fully developed, Passive Defense can also make hostile air attacks on the civil communities largely unprofitable from a military viewpoint; this is particularly true if the Passive Defense is adequate to prevent breakdown of the morale of the people.

It is not generally realized what enormous quantities of bombs and how extensive a military effort are required seriously to damage large communities. When this effort is diverted from purely military objectives, it necessarily greatly weakens the aggressive power of the state engaging in such tactics. Hence, the only justification for such direct air action against a civil population is the assurance that it will have such a devastating moral effect as to cause the population to compel its government to sue for peace. Any effect, short of this result, is more than questionable, for it is apt to bring about in a determined enemy population an even greater hostility and will to continue the war to a successful conclusion, at all costs.

The role of Passive Defense is therefore to prepare the civil population so that it can endure and resist all forms of hostile air attack without confusion and loss of morale and also carry on the normal work of the nation without serious impairment of efficiency. Passive Defense must also afford such protection to the industrial economy of the nation that it will not suffer a material dislocation of its machinery. If these objectives are achieved, it seems hardly possible that an opponent can win a decisive victory by direct pressure against the civil population alone. On the other hand, if Passive Defense fails to attain these ends, the chances for the nation successfully to survive a serious air war are more than doubtful.

CHAPTER I

RISE OF AIR POWER SINCE THE WORLD WAR

During the World War, military aircraft played a relatively minor role in influencing the major decisions of the War. Though sporadic air raids were made by both sides against each other's cities, the principal use of air forces was in aiding the tactical operations of ground troops. This was no doubt due principally to the limited range and performance capabilities of the airplanes then in use. Thus, the best bombers used in the World War had a speed of only approximately 100 m.p.h., a useful carrying capacity of 500 kg. (1,100 lb.), and an effective radius of action of about 350 miles. With these limitations in the performance of bombardment aircraft, it naturally resulted that they were used principally against targets in the theater of operations on the Western Front, as auxiliaries to the ground forces.

With the increase in range and bomb loads, made possible by the development of more powerful engines toward the latter part of the War, increasing attention was given to the possibility of using bombardment aviation on long range missions, independent of the action of ground forces. Nevertheless, the concept of an *independent air force,* capable of carrying out major strategical missions of coordinate importance with those assigned to armies and fleets, was only dimly foreshadowed in the last war. The German air raids on London and Paris and the Allies' retaliation on the German Rhineland cities were largely in the nature of side shows. They did not, to any appreciable extent, influence the progress of the War; about all they achieved was a mild harassment of the civil populations in these cities, and the diversion of some men and material to home defense from other fronts. Thus, the total number of casualties from 103 German air raids on England was 1,414 killed and 3,416 wounded. These casualties were produced by a total of 643 aircraft which dropped in all 8,776 bombs, in total weight about 270 tons.* Today an average bombing plane can carry 1½ tons of bombs; and even a relatively small attacking air force of 20 squadrons (270 planes) can, within a few minutes, drop 400 tons of bombs, or nearly double the total weight that fell on England during the whole 4 years of the World War.

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* "Air Defense and the Civil Population," pp. 44–45, Hyde and Nuttall, The Cresset Press, Ltd., London, 1938.

Another factor that greatly limited the effectiveness of air raids in the World War was the relatively small size and power of the high explosive bombs and the inefficiency of the incendiary bombs employed.

In the early days of the War, the prevailing type of high explosive bomb was the 100 kg. (220 lb.); the incendiary bomb weighed about 50 lb. The high explosive bomb functioned satisfactorily, but its destructive power was limited by its size. On the other hand, the early types of incendiary bomb, which employed tar and liquid hydrocarbons as incendiary agents, were almost wholly ineffective in producing fires, owing to faulty design and unsuitable materials.

Toward the end of the War, the prevailing type of high explosive bomb had increased to 300 kg. (660 lb.); this increase in size augmented their destructive effect. There were also reported instances of the use of even larger sized bombs, but the few isolated cases in which they were alleged to have been used appear to have been largely experimental trials.

In 1918 the incendiary bombs were also improved by reducing their size and increasing their incendiary efficiency by the use of thermite. Near the end of the War, the British introduced the Baby Incendiary bomb which consisted of a large number of small units, each weighing about ½ lb. and filled with thermite. These bombs proved effective against light inflammable targets and paved the way for the development in the postwar period of the high effective "electron" incendiary bomb now in use.

For reasons not altogether clear, the use of gas from airplanes was not attempted in the World War, although it appears that, at the time of the Armistice, both sides were experimenting with gas bombs and it is possible that they would have been used had the War continued beyond 1918.

The vast improvement in the range, carrying capacity, and performance of aircraft in the early years after the close of the World War immediately focused attention on the possibility of using aircraft as a *primary* arm in war, and the modern concept of air power, as a force coordinate with military and naval power, rapidly took shape.

In 1921, in his book entitled "Air Supremacy," the Italian General Guilio Douhet startled the world with his new concept of the role of air power in modern war. The main points of General Douhet's thesis may be summarized as follows:

1. In war on land the power of the defense is far greater than that of the attack and, therefore, victory can only be secured by the employment of vastly superior military forces. On the other hand, in the case of air attack, the power of the offensive is immeasurably greater than that of the defensive, since it is practically impossible to prevent a determined air attack from being pushed home, owing to the difficulty of finding and intercepting hostile bombers before they reach their objective. Because of the inherent impossibility of effective defense against it, air attack, without military or naval support, can compel a hostile state to surrender. This being the case, it follows that the Air Force must be regarded as the primary arm of national defense.
2. Since the Air Force is the primary arm of national defense, it should be made as large and powerful as the limits of national expenditure will permit and it must be completely independent of the Army and Navy.
3. The air arm is universal in action, for it can not only act against the hostile air, land, and sea forces, but most decisively of all, it can overleap embattled fleets and intrenched armies and strike directly against the enemy's capital and other vital objectives within his territory. Accordingly, the proper role of an Air Force is to act always on the offensive, while the Army and Navy maintain the integrity of the national frontiers by remaining strictly on the defensive.
4. If the foregoing premises are true, it necessarily follows that the greater part of national defense expenditures should be allocated to air armaments; the Army and Navy being maintained with only the minimum establishments required to ensure them against defeat by the military and naval forces most likely to oppose them.
5. Since the Air Force should always be at its maximum possible strength, all forms of cooperative air action with the Army and Navy should be abolished.
6. Fighting aircraft such as pursuit and intercept planes, should be eliminated, since they cannot prevent bombing raids and the cost of their construction and operation is at the expense of bombing aircraft, which is the real offensive power of the air arm.
7. Protection against hostile air attacks should be provided by the most efficient antiaircraft ground defenses, concentrated at vitally important points only, while the civilian population is protected by gas masks, protective clothing, and gas-, fire-, and bomb-proof shelters.
8. Finally, aeronautical research should be primarily devoted to increasing the range of endurance of the bombers, so that eventually no part of the enemy's territory shall remain immune from air attack.

One of the immediate effects of the Douhet theory of direct air action was the critical examination and reorientation of the national defense establishments in all the principal countries of the world, with a vast increase in the air armament of each. This world-wide interest in air power was soon reflected in vigorous and highly competitive efforts on the part of the leading world powers further to increase the power and capabilities of bombardment aircraft, and the phenomenal success achieved in this field soon made it apparent that air power would dominate the situation in future wars.

Viewing with alarm the rapid growth of aviation in the early years following the World War and foreseeing its almost unlimited potential power of destruction, unless restricted by some form of international agreement, the principal world powers made repeated but abortive efforts to arrive at some form of international agreement to prevent unrestricted air warfare, and particularly the bombardment of the civil populations of belligerent states.

Before considering the postwar efforts to regulate air warfare by international agreement, it seems desirable to glance briefly at the situation regarding bombardment of cities generally, as it existed before and during the World War.

Up until 1899 the traditional rule, under the "custom of war," was that a *fortified* city was subject to bombardment, whereas an unfortified city was not. In 1899 the first Hague Conference adopted the view that immunity of a city from bombardment depended entirely upon whether or not it was *defended*. Up to that time the sole means of bombardment envisaged was by artillery fire.

Between 1899 and 1907 the increasing use of balloons in warfare caused the second Hague Conference of 1907 to insert in the prohibition of bombardment the phrase "by any means whatever" so as to place air bombardment in the same category with artillery fire. However, with respect to bombardment by naval forces, the 1907 convention introduced a new doctrine. Though still forbidding the bombardment of undefended towns, it permitted a naval force to bombard "military works, military or naval establishments, depots of arms or war material, workshops or plants which could be utilized for the needs of the hostile fleet or army." Here we see introduced for the first time the principle of the "military objective" and the "separability of the target," for the naval commander may now fire into an undefended port, under certain conditions, and, if he uses due care to avoid unnecessary damage to other places, he incurs no responsibility for any unavoidable damage under such circumstances.

During the World War, there was wide divergence between theory and practice with respect to air bombardment, and little or no unity of viewpoint regarding rules of air warfare generally. In theory at least, the principle of the military objective seems to have been widely accepted; and the prevailing practice, as asserted on both sides, was to bomb only objectives of military importance wherever situated, with due care to avoid unnecessary damage to nonmilitary life and property. Although the actual results of air bombardments in the World War deviated widely from the principle of the military objective, this doctrine was predominant in all discussions of air bombing during the war; each belligerent insisting that he strictly observed the rule whereas his opponents violated it. The situation was still further complicated by the introduction of a new criterion of the legitimacy of air bombardment, *viz.*, the principle of retaliation or reprisal, and every air bombing operation that clearly violated the principle of the military objective was justified on the ground of reprisal for some alleged prior violation of the rule by the other side. Such was the situation concerning air warfare at the end of the World War.

The first postwar effort to restrict air combat by international agreement was made by a commission of jurists sitting at the Hague in 1923. This commission drafted a comprehensive code of rules for the regulation of air warfare. Of these rules the following articles are sufficiently pertinent to be quoted in full:

> ARTICLE 22. Aerial bombardment for the purpose of terrorizing the civilian population, of destroying or damaging private property not of military character, or of injuring noncombatants is prohibited.
>
> ARTICLE 23. Aerial bombardment for the purpose of enforcing compliance with requisitions in kind or payment of contributions in money is prohibited.
>
> ARTICLE 24. 1. Aerial bombardment is legitimate only when directed at a military objective, that is to say, an object of which the destruction or injury would constitute a distinct military advantage to the belligerent.
>
> 2. Such bombardment is legitimate only when directed exclusively at the following objectives: military forces; military works; military establishments or depots; factories constituting important and well-known centers engaged in the manufacture of arms, ammunition or distinctly military supplies; lines of communication or transportation used for military purposes.
>
> 3. The bombardment of cities, towns, villages, dwellings or buildings not in the immediate neighborhood of the operations of land forces is prohibited. In

cases where the objectives specified in paragraph 2 are so situated that they can not be bombarded without the indiscriminate bombardment of the civilian population, the aircraft must abstain from bombardment.

4. In the immediate neighborhood of the operations of land forces, the bombardment of cities, towns, villages, dwellings or buildings is legitimate provided that there exists a reasonable presumption that the military concentration is sufficiently important to justify such bombardment, having regard to the danger thus caused to the civilian population.

5. A belligerent state is liable to pay compensation for injuries to person or to property caused by the violation by any of its officers or forces of the provisions of this article.

It will be noted that Article 24 declares that aerial bombardment is legitimate only when directed at a *military* objective and that bombardment of such objectives is legitimate only when it is directed "exclusively" against them. Furthermore, the only *persons* who may be bombarded are "military forces." This would apparently not include civilian munitions workers, although there would seem to be no reason why they should be entitled to the immunities of noncombatants, when they are in effect almost the same as men engaged in the supply and auxiliary services of the army. However, since munitions factories and other establishments in which they work may be bombed, their immunity covers them only while they are at home. Though it may be argued that, when in their homes, munition workers are in no way different from the ordinary population, the same may be said of purely military personnel, so that it may be doubted whether the distinction is sound.

It will be further noted that the criterion set up in Article 24 is whether the object to be bombed is one the destruction or injury of which would constitute a "distinct military advantage" to the attacking belligerent. Although this is a reasonable and sound rule that has been widely approved by those who have carefully studied the matter, it has the defect of any rule seeking to restrict aerial bombardment to specified objects that are situated in urban communities and are immediately surrounded by other objects and persons that it is forbidden to bomb. The inherent difficulty is that aviators cannot possibly confine their bombs "exclusively" to such objects.

It was largely on account of such obvious and inherent difficulties as these that the Hague Air Warfare Rules of 1923 were not ratified, even by the participating countries.

Concerning these rules, Dr. J. M. Spaight* concludes,

> The rules remain a draft. They have not as yet been incorporated in a Convention, still less has any Convention been ratified by any contracting Powers. They represent, however, the considered opinion of a body of jurists of distinguished ability and are therefore to be regarded as constituting a statement of the "common law" of nations upon this subject, as understood by eminent legal authority.
>
> They start from the unchallenged principle of the military objective. It is in their translation of that principle that they are open to criticism!

A second effort to restrict air warfare by international agreement was made at the Geneva Disarmament Conference of 1932–1934. The principal proposals discussed at this conference were the following:

> 1. Abolition of all air bombardment, except for police purposes in certain outlying regions.
> 2. Complete abolition of military and naval aircraft and effective supervision of civil aviation to prevent its misuse for military purposes.
> 3. Pooling all bombardment aircraft under an international authority for the purpose of preventing aggression.
> 4. Restriction of bombing aircraft to certain permissible types.

The common weakness of all these schemes is that they require some form of international supervision and control to make them really effective; an unscrupulous state may, by secret measures, completely circumvent the restrictions and thus gain a tremendous material advantage in a war with another state that has conscientiously abided by the rules. For these and other reasons the efforts of the Geneva Disarmament Conference came to nothing, failing with the failure of the conference as a whole.

The latest proposal for limiting air bombardment by international agreement is the resolution adopted by League of Nations Assembly, Sept. 10, 1938, which recognizes the following principles as a necessary basis for any subsequent regulations:

> (1) The intentional bombing of civilian populations is illegal;
>
> (2) Objectives aimed at from the air must be legitimate military objectives and must be identifiable;
>
> (3) Any attack on legitimate military objectives must be carried out in such a way that civilian populations in the neighborhood are not bombed through negligence; . . .

---

* In "Air Power and the Cities," p. 211, Longmans, Green & Company, London, 1930.

It is doubtful whether this latest proposal will be any more successful in practical results than its predecessors, for the same inherent difficulties remain. The term "military objective" is still practically impossible adequately to define, and it is equally impossible to determine whether a bombardment of the civil population was intentional, negligent, or unavoidably incident to the bombing of legitimate military objectives.

All in all, it is hard to see how the future security of civilization is to be obtained by the regulation of air warfare through international agreement. Aside from the inherent difficulties of this complex question, the precedents of history are all against reposing confidence in this form of remedy. The classic example of the folly of such a course of action is the failure of the Hague Convention to prevent gas warfare in the World War.

If any lesson is to be learned from the experience of the past, it is that, when a nation at war is hard pressed by its enemies, it will use any and every means of warfare which it believes will be of any advantage in winning the war, solemn treaties and international agreements to the contrary notwithstanding.

If the potentialities of air attack are such that it can really exert a crushing moral effect upon a nation and thus prove decisive by itself, it seems inevitable that air power will eventually prevail over the slower and more uncertain effects of military and naval action. This view is ably expressed by one of the world's leading military authorities, the British General P. R. C. Groves, who was for many years Director of Flying Operations of the British Air Ministry. In his excellent book, entitled "Behind the Smoke Screen,"* he writes,

> In Europe, warfare hitherto primarily an affair of fronts will be henceforth primarily an affair of areas. In this "War of Areas" the aim of each belligerent will be to bring such pressure to bear upon the enemy people as to force them to oblige their government to sue for peace. The method of applying this pressure will be by aerial bombardment of national nerve centers, chief among which are the great cities. Existing air fleets are capable of inflicting destruction on a cyclonic scale, and they are constantly growing. It seems highly probable, therefore, in a future conflict, if any great disparity should exist between the strengths in the air of the belligerents, that the stronger will quickly overwhelm the opponent, possibly even before the latter could bring its naval and military forces to bear.

* Faber & Faber, Ltd., London, 1934.

Although there is today no internationally recognized code governing air warfare, it is clear from what has been said above that the only practicable basis for any rules of air bombardment must be the principle of the military objective. In the past, not only has this principle governed naval bombardment, by virtue of international convention and actual usage among nations, but it has also been generally recognized as applicable to air bombardments during and since the World War. It is true that in air bombardments the principle of the military objective has been often seemingly "honored in the breach," but these instances may be generally attributed to the difficulty of practically applying the principle rather than to deliberate attempts to deviate from it.

The theory of the military objective is simple and is clearly stated in the Hague Air Warfare Rules of 1923 (see page 13). The difficulties arise in the practical application of these rules.

From the standpoint of the noncombatant civil population, one of the chief difficulties in connection with air bombardments occurs when legitimate targets, such as munitions factories, are situated in thickly settled communities, for it is impossible to destroy such factories without injuring the surrounding civilian residents. Experience in and since the World War has shown conclusively that factories in large cities cannot be successfully bombed without great damage to the surrounding community. In fact, whenever an attempt was made to bomb such a factory, the surrounding community generally sustained far greater injuries than the factory.

On the assumption that an honest effort is made by a bomber crew to confine its attacks to legitimate military objectives, there are many factors that enter into the situation to modify greatly the results of such efforts. Chief among these factors are darkness, thick weather, camouflage of the target, and the disturbing effects of defending aircraft, antiaircraft artillery fire, and balloon barrages. When these deterrent influences are present, even with the best intentions, the bombs will fall wide of the target and may indeed miss it altogether. Though it is true that bomb sights and accuracy of bombing under normal conditions have greatly improved since the World War, no amount of technical excellence in equipment can ensure accuracy of bombing under adverse conditions such as those mentioned above.

The natural result of the difficulty of confining the effects of air bombardments to legitimate targets is to cause the enemy to charge that the bombing of civilians in the surrounding areas has been either indiscriminate or deliberate, and retaliation in kind inevitably follows. It thus arises that soon after air bombardments commence, no matter in what good faith they may have been initially conducted, a situation is soon reached where indiscriminate if not deliberate attacks are made against the civil communities on both sides.

The situation is even worse for the people where a belligerent state openly embraces the doctrine of direct action against the civil population in order to achieve victory. Here, there are practically no restraints upon a belligerent's air activities; and the most appalling slaughter of women, children, and other noncombatants may be expected. This is indeed the most serious situation confronting the nations of the world today. Until there is a return to reason and sanity in the conduct of war, the only alternative is the maximum air defense, both active and passive, that is possible of attainment by the utmost organization of all the resources of the country and the people.

During the two decades since the World War, technical improvement in airplane design and the enormous increase in the power of airplane engines have more than tripled the speed and range of bombardment planes and increased their carrying capacity from five- to sixfold over that of the best bombers in use 20 years ago. Now bombers are in actual use with a speed of 300 m.p.h., an effective radius of action of at least 1,000 miles, and a bomb-carrying capacity up to 6 tons.*

Hand in hand with this remarkable development in airplane performance has gone an equally impressive development of aircraft armament. High explosive bombs have been increased in size and power, so that today 2,000-lb. bombs are in common use and high explosive bombs weighing as much as 4,000 lb. have been developed. The efficiency of the incendiary bomb has been vastly increased so that now it is capable of causing widespread conflagrations even from a single bomber. Gas bombs and sprays have also been developed to a point where a relatively few planes could seriously contaminate large areas of ground and cause widespread casualties among all unprotected persons in such areas.

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* The United States bomber B-17 ("Flying Fortress") has the following characteristics:

Length, 70 ft.
Wing span, 105 ft.
Total flying range, 3,000–4,000 miles
Effective flying range, at least 1,500 miles
Ceiling, 40,000 ft.
Speed, 250 m.p.h.
Total weight, 20 tons
Munitions load, 5 tons
Crew, 7–9
Gun emplacements, 5
Motors, 4 1,000 hp.

These various means of air attack will be dealt with at length in subsequent chapters and are mentioned here only to indicate in outline the vast potentialities of air warfare today. With this formidable armamentarium and combat planes numbered by the thousands, and probably by the ten thousands in the near future, the nations of the world seem fully justified in regarding their air defense establishments as their first and foremost concern.

CHAPTER II

MEANS AND EFFECTS OF AIR ATTACK

We have seen that the armament of the modern bomber comprises high explosive, incendiary, and gas bombs, chemical sprays, machine guns, and light cannon and that these last two weapons are not normally used against ground targets, so that Passive Defense is concerned with protection of the civil population only against the first four.

BALLISTICS OF BOMBS

Before considering the nature, functioning, and effects of the various types of bomb, it is useful to know something of the ballistic characteristics of bombs in general.

Trajectory.—At the instant of release from an airplane a bomb has the same forward speed as the plane. Immediately after release the forward speed of the bomb begins to diminish, owing to air resistance; but its vertical speed increases, under the influence of gravity, at a progressively increasing rate as it falls to the ground. The path described by the bomb is substantially parabolic, the shape of the parabola being dependent upon air resistance, the initial horizontal speed of the bomb, and the vertical distance through which it falls (see Fig. 1).

Vertical Speed.—The vertical speed of a bomb, however, does not increase indefinitely with the altitude from which it is dropped, owing to the fact that as its velocity increases the air resistance also increases; eventually a point is reached where the retardation due to air resistance equals the acceleration of gravity, and the bomb then travels with a constant speed. This balance of forces generally occurs when a large bomb attains a velocity of about 1,000 ft. /sec., which is usually attained after it has fallen from an altitude of about 25,000 ft.

Range.—The horizontal distance that a bomb travels from the instant of its release from the plane to the time it strikes the ground is called its *range*. In Fig. 1, it will be noted that the range is the horizontal projection of the flight path, or trajectory, of the bomb and is equal to the distance on the ground from a point vertically beneath the point of release to the point of impact of the bomb.

Angle of Fall.—The angle that a bomb makes with the horizontal at the instant it strikes the ground is called its *angle of fall.* The striking inclination of a bomb is also expressed in terms of the angle that the bomb makes with the *vertical* at the moment of impact. This is generally called the *angle of impact* and is equal to 90° minus the angle of fall. The principal factors affecting the angle of fall are altitude and air speed. In general, the greater the altitude, the larger the angle of fall; but the greater the air speed, the smaller the angle of fall. The angle of fall is an important factor in the penetrating power of the bomb. Since maximum penetration is attained when the angle of impact is normal

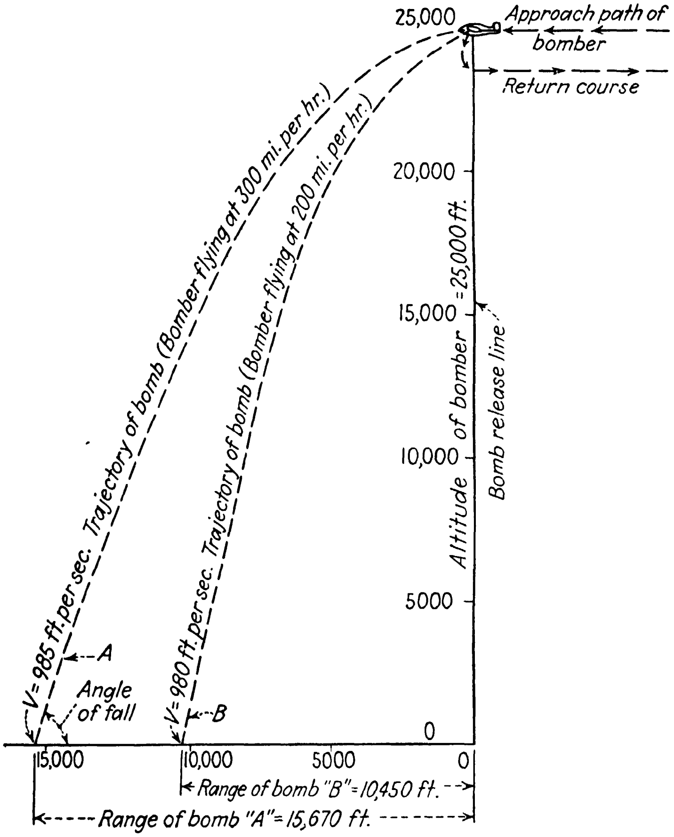
25,000
Approach path of bomber
Return course
20,000
15,000
10,000
5000
0
Altitude of bomber = 25,000 ft.
Bomb release line
V = 985 ft. per sec. Trajectory of bomb (Bomber flying at 300 mi. per hr.)
V = 980 ft. per sec. Trajectory of bomb (Bomber flying at 200 mi. per hr.)
A
Angle of fall
B
15,000
10,000
5000
0
Range of bomb "B" = 10,450 ft.
Range of bomb "A" = 15,670 ft.

Fig. 1.—Bomb trajectories.

(90°) to the surface of the target, in general the larger the angle of fall, the greater the penetration of the bomb.

Time of Flight.—The time required by a bomb to fall down from its point of release to its point of impact is called its *time of flight.* Time of flight is practically independent of initial horizontal velocity (air speed). Thus, the time of flight of a bomb, released at 10,000 ft. from a plane flying 150 m.p.h., is 25.93 sec., whereas the time of flight of the same bomb, released at the same altitude, from a plane flying 300 m.p.h., is 26.15 sec. Thus, doubling the air speed increases the time of flight by only 0.22 sec.

Maximum Velocity.—The minimum altitude from which a falling bomb attains its maximum velocity is not constant, for the speed of a falling bomb depends also upon its size, shape, and density. Thus, a large bomb falls faster than a small one of the same density and similar shape, for the reason that, as the size of a bomb is increased (its shape and density remaining constant), its weight increases at a greater rate than the air resistance. Thus, if one bomb is twice the size of another and has the same shape and density, the larger bomb will have eight times the weight of the smaller one but only four times the air resistance in flight. Hence, the altitude from which a bomb attains maximum velocity depends principally upon its size, for all bombs have substantially the same shape and their densities vary only within relatively narrow limits. Accordingly, the altitude of 25,000 ft. mentioned above applies only to large bombs; and as the size of the bomb decreases, the altitude from which it attains maximum velocity also decreases. Thus, the smallest bomb in use today (the 2-lb. incendiary) attains its maximum velocity of about 350 to 400 ft./sec. from an altitude of approximately 5,000 ft.

Impact Velocity.—The velocity of a bomb at the instant of impact is called its *impact* or *striking velocity* and is the principal factor governing the penetration of the bomb into the medium which it strikes. As indicated above, the maximum striking velocity of a large bomb is approximately 1,000 ft. per second; that of a small bomb, about 400 ft./sec.

Mean Range Error.—If a bombing plane is kept at as nearly a constant speed and altitude as possible and if the bombs have perfect flight, then their points of impact will be in the line of flight and at distances from each other equal to the speed of the airplanes multiplied by the difference in times of release. Any deviations of the actual points of impact from the theoretical impact points are due to the ballistic inaccuracies of the bombs. These deviations determine the ballistic accuracy of the bomb, and the average deviation is known as the *mean ballistic range error* for such bombs.

Ballistic Characteristics.—Table I shows the ballistic characteristics of bombs, weighing 100 to 2,000 lb., when dropped at different altitudes from planes flying at 200 to 300 m.p.h. As nearly all modern bombers fly at speeds between 200 and 300 m.p.h., the figures shown in Table I may be regarded as the minimum and maximum values of the ballistic characteristics indicated.

TABLE I

BALLISTICS OF AIRCRAFT BOMBS

(Weighing 100 to 2,000 lb.)

Dropped from Aircraft

Altitude, ft.	Horizontal range, ft.[a]	Angle of fall, deg.[b]	Time of flight, sec.[c]	Impact velocity, ft./sec.[d]	Mean range error, ft.[e]
Flying 200 m.p.h.					
1,000	2,270	40.0	7.97	377	15.0
5,000	4,950	64.5	18.13	590	32.5
10,000	6,990	72.3	26.00	754	50.0
15,000	8,370	76.0	32.19	852	70.0
20,000	9,590	78.5	37.64	923	90.0
25,000	10,450	80.5	42.70	980	110.0
Flying 300 m.p.h.					
1,000	3,380	20.0	7.99	520	15.0
5,000	7,310	52.5	18.23	659	32.5
10,000	10,180	63.5	26.15	803	50.0
15,000	12,380	69.4	32.31	855	70.0
20,000	14,160	73.0	37.80	926	90.0
25,000	15,670	75.4	43.00	985	110.0

[a] Values are for no wind and are accurate to within approximately 3 per cent.

[b] Values are for no wind and are accurate to within approximately 1 per cent.

[c] Values are for no wind and are accurate to within approximately 2 per cent.

[d] Values are for no wind and are accurate to within approximately 5 per cent.

[e] The mean ballistic error in deflection will approximate that for range, provided that the bombs are properly released.

HIGH EXPLOSIVE BOMBS

Types.—There are three principal types of high explosive bomb in use today, *viz.: demolition* bombs, *general purpose* bombs, and *fragmentation* bombs. All carry high explosive charges, varying from about 40 per cent of the total weight of bomb, in the case of fragmentation bombs, to approximately 60 per cent in the case of the larger sized demolition bombs (see Figs. 2, 3, and 4).

As the name indicates, *demolition* bombs are designed for demolishing targets. They vary in size from 300 kg. (660 lb.) to 1,800 kg. (4,000 lb.), the most frequently used being the 300- and the 500-kg. sizes. Since only one 1,800- or two 1,000-kg. demolition bombs can be carried, even by the larger bombers, their use is restricted, in comparison with the smaller sizes, and they are reserved for special targets of great size and strength, such as massive bridges, canal locks and dams, and large buildings.

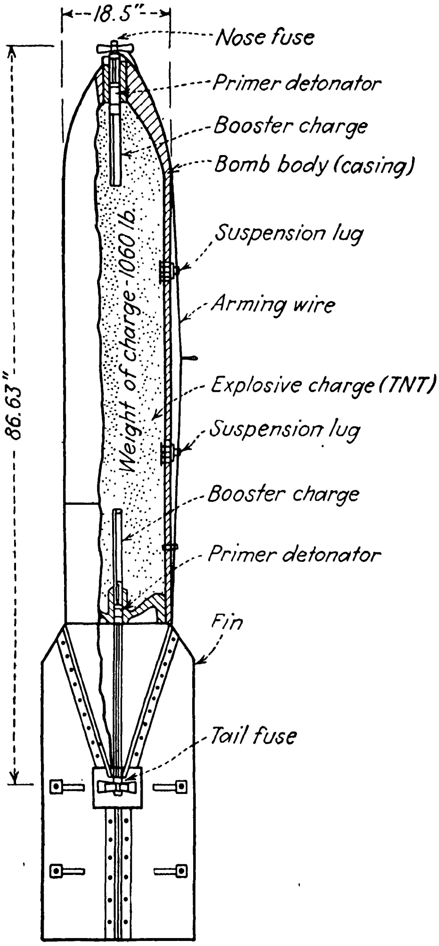

FIG. 2.—Demolition bomb (2,000 lb.).

The *general purpose* bomb is a medium-case bomb of intermediate weight (20 to 250 kg.); it may be used with or without some element of delay in fuse action. Such bombs will penetrate the upper floors of ordinary buildings and explode, causing considerable damage inside, or may demolish unprotected buildings by their blast effect if they explode close to the building on the ground outside. Since these bombs are designed to produce effect mainly by blast, they are ineffective against specially protected or very massive structures and deep targets.

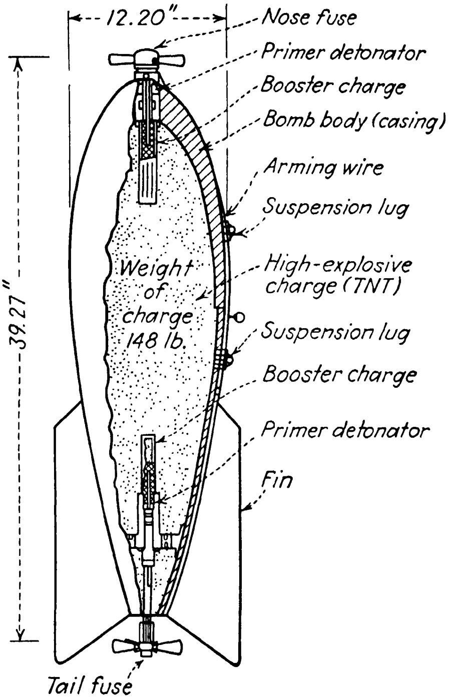

FIG. 3.—General purpose bomb (300 lb.).

As the average bombardment plane can carry ten 100- or four 250-kg. general purpose bombs, as compared with two 500- or one 1,000-kg demolition bombs and the former are effective against the great majority of targets, they are the types most frequently used for ordinary bombing missions.

The *fragmentation* bomb is a small bomb, usually varying in weight from 10 kg. (22 lb.) to 25 kg. (55 lb.); it is designed primarily for attacks on personnel. Such bombs produce their effect primarily by fragments scattered over a wide area and have very limited blast effect. Since penetration is not required, fragmentation bombs have light casings and are fitted with instantaneous fuses; they have only slight powers of penetration, and hence little cover is required to afford protection against them.

They are generally used in large quantities against personnel in open areas.

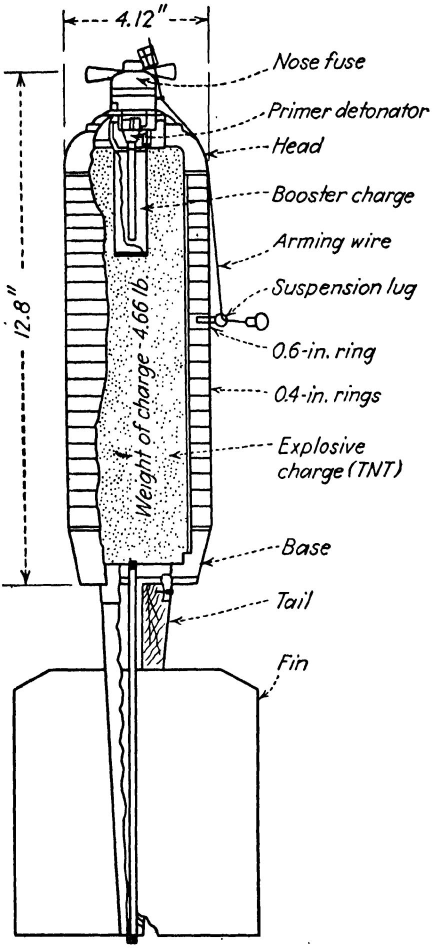

FIG. 4.—Fragmentation bomb (30 lb.).

Explosives.—In order to understand the effects produced by high explosive bombs, it is necessary to know something of the nature of high explosives and of the sequence of events when a bomb bursts. In general, an explosive is a substance (usually a solid) which, when subjected to heat and /or shock, is converted almost instantly into a very much larger volume of gas at a very high temperature and pressure. The hot compressed gas expands and ruptures the bomb casing with a force that depends primarily upon the volume of gas, per unit weight of explosive, and the rate at which the solid explosive is converted into gas.

Classification of Explosives.—Explosives are classed as *low* or *high* according to the speed at which the conversion from solid to gas takes place. A low explosive is converted by a process of rapid combustion whereas a high explosive functions in a far more rapid manner, known as *detonation*. Thus, the time required for the detonation of the high explosive charge of a 500-lb. bomb is of the order of 1 /10,000 of a second.

Explosive Factor.—The destructive effect of an explosive is due, not so much to its potential energy, as to the extremely rapid rate at which that energy is developed. Thus, the characteristic effect of a low explosive is that of a *push*, whereas a high explosive *shatters*. The shattering power, or *brisance*, of a high explosive is a product of its weight per unit volume (density), times the volume of gas per unit weight, times the heat generated per unit weight, times the velocity of detonation. The *brisance* of an explosion is measured in terms of the shattering power of standard black powder, and the number of times this power of the explosive exceeds that of black powder is called its *explosive factor*. The explosive factors of high explosives used in military operations generally vary between 2.5 and 3.0. This factor is used in calculating the effects of an explosion (see page 39).

Fuses.—When a falling bomb strikes an object, the impact causes a needle in the fuse of the bomb to pierce a cap containing a very sensitive explosive, usually fulminate of mercury, which detonates and in turn sets off the main explosive charge of the bomb. Aircraft bomb fuses may be fitted to either or both ends of the bomb and are of two types: (1) *instantaneous*, which causes the bomb to burst immediately on contact with the target; or (2) *delay*, which causes the bomb to burst after a predetermined time interval and thus enables it to penetrate the target before exploding.

Destructive Power.—The destructive power of a high explosive bomb is the resultant of its several effects which are produced in approximately the following sequence: (1) impact; (2) penetration; (3) blast; (4) fragmentation; (5) cratering; and (6) rupture or mining effect. Although these successive stages are distinguished for purposes of study and evaluation, it must be borne in mind that they occur almost simultaneously, and their effects cannot be countered selectively.

Impact and penetration effects of falling bombs are generally determined by dropping inert bombs of different sizes from various altitudes upon targets of various materials, such as natural earth, clay soil, gravel, hard rock, and concrete. By using inert bombs the damage due to shock of impact and the penetration of the bomb in various substances may be determined apart from the effects of explosion. Similarly, the effect of explosion can also be determined, apart from those of impact and penetration, by static tests in which the bomb is placed in various positions with respect to the surface of the target and exploded in place. In this manner

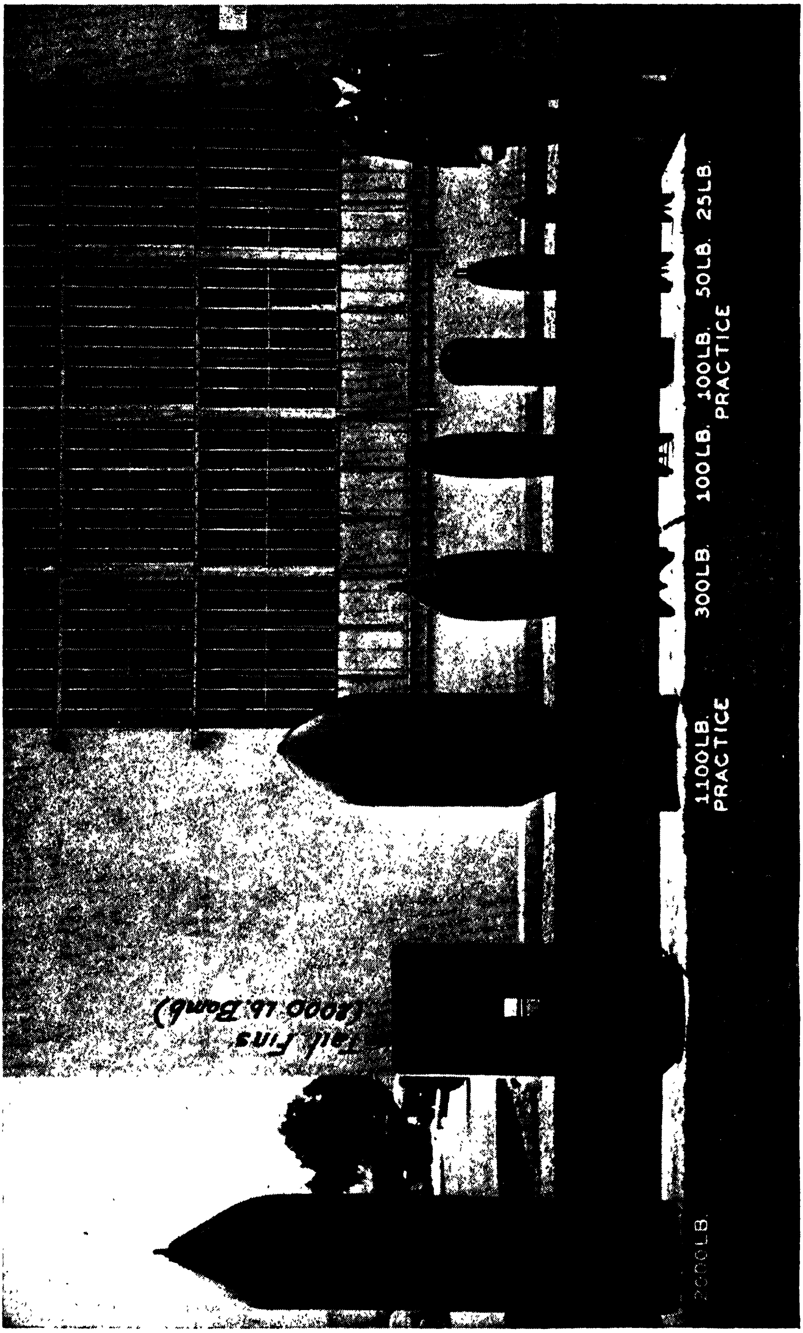

FIG. 5.—Various sizes of bombs.

the damage caused by explosion may readily be distinguished from that caused by impact and penetration.

By means of extensive field trials, the several factors affecting the behavior of bombs under various service conditions are determined and, by correlation with the laws of dynamics, empirical formulas are worked out to express the various effects produced under known conditions.

Impact.—When a falling bomb strikes a target, particularly a building or structure, its first effect is to produce a sudden load on the structure due to the retardation of the bomb by the resisting medium of the structure. The stress imposed upon the structure by the retardation of the bomb depends upon the kinetic energy of the bomb, and is expressed by the formula

$$K = \frac{WV^2}{2g}$$

where K is the kinetic energy, in foot-pounds.

W is the total weight of the bomb, in pounds.

V is the impact velocity, in feet per second.

g is the acceleration of gravity, in feet per second per second = 32.2.

A 660-lb. bomb with an impact velocity of 1,000 ft./sec. develops a kinetic energy of

$$\frac{660 \times 1{,}000^2}{2 \times 32.2} = 10{,}000{,}000 + \text{foot-pounds}$$

If this bomb is brought to rest after it has penetrated into a reinforced concrete slab for a distance of 1 ft., it has imparted to the slab an impact load of 10,000,000 lb. The distribution of this impact load may be assumed as spread over a cone of 90° at the apex.

Penetration.—The damage wrought by a high explosive bomb depends to a considerable degree upon the depth to which the bomb penetrates the target before explosion occurs. This is not only because the effects of impact and explosion are thus additive, but more particularly because the explosive gases are more confined by penetration and hence exert a greater disruptive effect.

Much time and effort have been expended in attempts to devise an exact formula to express the depth to which a given projectile will penetrate into different substances. For practical purposes the simplest and most satisfactory formula for this purpose is that devised by Petry* in 1910, as follows:

$$S = K \times \frac{W}{d^2} \times fV$$

where S is the depth of penetration, in meters.

K is a constant.

W is the weight of projectile, in kilograms.

d is the diameter of projectile, in centimeters.

f (V) is a function of the impact velocity V.

The coefficient K has the following values:

Soft soil	5.87
Soil with vegetation	3.86
Sandy soil	2.94
Brick masonry	1.63
Stone masonry	0.94
Concrete (plain)	0.64
Limestone	0.43
Concrete (reinforced)	0.38[a]

[a] Value given by M. Bazant in "The Use of Reinforced Concrete for Fortifications and Air Raid Shelters," in *Travaux* Nos. 52 and 53 (April and May), 1937, for concrete of 2,800 lb./sq. in. strength.

$f(V)$ has the following values in the kilogram-meter-second system (except that d is in centimeters):

V	$f(V)$	V	$f(V)$
40	0.33	220	5.34
60	0.72	240	5.89
80	1.21	260	6.41
100	1.76	280	6.92
120	2.36	300	7.40
140	2.97	320	7.87
160	3.58	340	8.31
180	4.18	360	8.74
200	4.77	400	9.54

Figure 6 shows graphically the depths of penetration of bombs of unit sectional density, falling with different velocities and striking various mediums at normal incidence (*i.e.*, angle of fall 90°). The approximate maximum penetration of any given bomb may be calculated from these curves by multiplying the values on any curve by the sectional density of the bomb (see Table II, page 44).

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* See "Exterior Ballistics," Cranz and Becker, His Majesty's Stationery Office, London.

As the angle of incidence from the normal increases (*i.e.*, as the angle of fall decreases), the depth of penetration decreases, until a certain angle of fall is reached where the bomb will merely

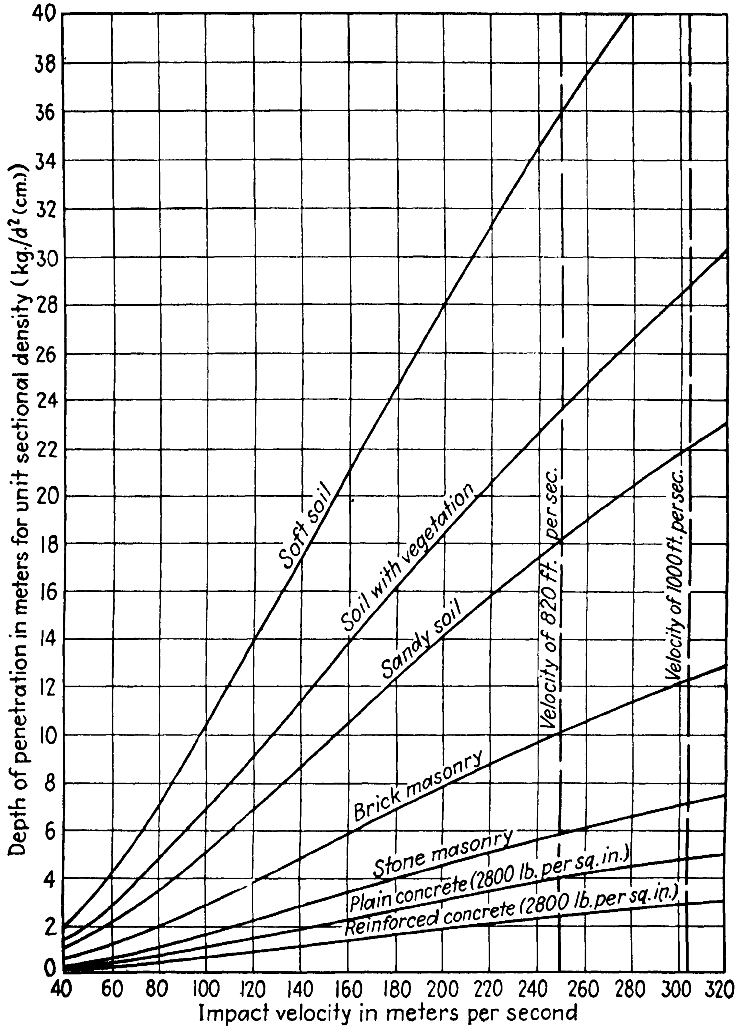


FIG. 6.—Bomb penetrations. Petry's formula (page 30).

ricochet without appreciable penetration. For all ordinary angles of fall the bomb generally deviates from its course in an upwardly curving path after penetrating a certain distance. In certain low-resistance mediums, such as ordinary soil, clay, and loose gravel, this deviation from a straight line often exceeds the vertical depth of penetration by as much as 30 per cent, so that, although vertical penetration is the paramount consideration in designing underground shelters, lateral protection must not be overlooked, for otherwise a shelter with adequate overhead cover may be penetrated laterally if its side walls are too close to an exposed surface of the ground. Since the angle of fall is never quite 90° but approaches that angle as a limit at maximum bombing altitudes and since an impact velocity of 1,000 ft./sec. is attained only at maximum bombing altitudes, the depths of penetration obtained from the curves in Fig. 6 are maxima and are rarely exceeded in actual practice.

When a bomb falls on certain highly resistant mediums, such as rock, chalk, and concrete, its penetration may be largely negatived by a failure of the bomb casing. As a rule, *demolition* bombs are provided with heavy casings, specially designed to penetrate the most resistant mediums, and hence their penetration depths are comparatively definite. On the other hand, in the case of *general purpose* bombs, the bomb cases are much lighter and, not being designed specifically for penetration, are liable to deformation on impact especially when fitted with delay action fuses, and the depth of penetration is thus very uncertain. In order, therefore, to estimate the probable penetrative capacity of medium-case bombs, it is necessary to compare them with heavy-case demolition bombs and note that they possess a certain percentage of penetrative capacity, according to the material encountered.

Actual field trials with medium-case general purpose bombs have shown the following relative penetrative capacities with respect to heavy-case demolition bombs:

Soil	Relative Depth of Penetration
Earth, sand, and gravel	1
Chalk	⅔
Concrete, rock	⅓

Hence, if the maximum vertical penetration of a typical 660-lb. heavy-case demolition bomb in chalk is 21 ft., a medium-case general purpose bomb would penetrate 21 × ⅔, or 14 ft.

The penetration of falling bombs into masonry and concrete structures depends to a large degree on the nature of support of that part of the structure which the bomb strikes. If the portion of the structure struck by the bomb is an unbacked slab, *i.e.*, a slab having an air space on its rear face, with nothing behind it to absorb the shock of impact, it is far more readily penetrated than a slab of equal thickness supported by earth or other contacting medium.

When a bomb moving with a high velocity strikes a hard surface, such as concrete, it causes a very high stress over the area of impact. This stress is transmitted through the slab as a compression wave with the velocity of sound, which for solid substances, such as concrete, approximates 14,000 ft./sec. When the compression wave reaches the rear face of the slab, it causes tensile stresses far beyond the cohesive resistance of the concrete and tears off a circular portion of the slab somewhat larger than the area of impact. The result is that a wide, shallow circular crater is formed in the rear surface of the slab.

If, on the other hand, the slab is backed up by a supporting medium, such as earth, the supporting medium absorbs a large portion of the compression wave and thus materially reduces the stresses in the slab. This enables the slab to resist penetration of the bomb and decreases the depth of penetration and the size of the resulting crater.

Thus, a 660-lb. general purpose bomb striking a multistoried, reinforced concrete building, having floors 6 in. thick, will perforate six floors, or a total of about 36 in. of reinforced concrete, whereas the same bomb will penetrate a single reinforced concrete slab, supported over its whole surface, to a depth of only about 1 ft.

Blast.—When the high explosive charge in a bomb detonates, each cubic inch of explosive is instantly converted into about 1,000 cu. in. of gas, at normal temperature and pressure. At the temperature of explosion the potential volume of gas is at least 10 times that amount, so that upon detonation the high explosive charge expands to something in the order of 10,000 times its original volume. The pressure of the gas confined within the bomb case is in the order of 500 tons/sq. in. This enormous pressure causes the metal bomb case to swell to about 150 per cent of its original volume, at which point the breaking point of the metal is reached and the case bursts into fragments, liberating the compressed gas into the atmosphere. The air in contact with the escaping gas is suddenly compressed, and an intense air pressure, or shock wave, is formed in the air immediately surrounding the exploding bomb. This sudden air pressure is known as "blast" and is essentially a shock wave that travels outwardly with an initial velocity in the order of 7,000 ft./sec. As this wave travels outwardly from its source, it decreases in amplitude and velocity and eventually becomes stable at the velocity of sound, *i.e.*, 1,100 ft./sec.

The shock wave generated by the blast from a bomb exploding in the open air consists of an initial positive pressure phase followed by a negative (suction) phase of much less intensity but longer duration. The total duration of the combined positive and negative phases is about 0.030 sec., of which the former is about 0.005 sec. and the latter, 0.025 sec.

Blast pressure is inversely proportional, approximately, as the cube and then as the square of the distance from the center of explosion, so that the outward movement of the expanding gases probably does not exceed about 25 ft. when a bomb bursts on a flat surface in the open air, although the shock wave is propagated through the surrounding air to much greater distances depending upon the size of the explosive charge.

The variations, with distance from point of explosion, of the initial maximum positive and negative pressures are indicated by the following tabulation, for a 250-kg. medium-case general purpose bomb:

INITIAL MAXIMUM PRESSURES
250-kg. Medium-case General Purpose Bomb

Distance from bomb, ft.	Maximum positive pressure, lb./sq. in.	Maximum negative pressure, lb./sq. in.
30	24.0	2.0
50	6.0	1.4
100	2.3	0.8
200	0.4	0.2

The effect of blast upon a structure depends, not only on the magnitude of the initial air pressure, but also on the natural frequency of vibration of the structure against which the shock wave strikes. It is therefore necessary to reduce the pressure-time curves of blast waves to an "equivalent static pressure," *i.e.*, the pressure which if applied steadily to the structure would produce the same maximum stresses as that produced by the wave itself. Where the frequency of vibration of the structural system is relatively high, the equivalent static pressure is generally greater than the actual maximum pressure of the blast and may even be double the latter. On the other hand, where the frequency of the structural system is relatively low, the values of the equivalent static pressure, both positive and negative, are much lower than the pressures of the blast but increase rapidly as the frequency increases and attain values approximating the maximum pressure in the blast for systems of frequency of 40 cycles per second or over.

Buildings as a whole have relatively low frequencies of vibration, averaging approximately 7 cycles per second. However, certain parts of buildings, such as wall panels, generally have much higher frequencies, ranging from 20 cycles per second for a panel 10 ft. square and 4½ in. thick to 45 cycles per second for a panel 10 ft. square and 9 in. thick. In general, it has been found that brick walls 9 in. or more in thickness can safely withstand equivalent static pressures of 3 to 6 lb./sq. in. that are produced by the blast from a 250-kg. general purpose bomb exploding in the open air at a distance of 50 ft. from the wall.

The foregoing discussion of blast effect has been based upon the premise that the bomb bursts in the open air. If, on the other hand, the explosion occurs within a building or other confined space, the resulting damage will generally be much greater. This is due both to the increased blast pressure produced by the confined space and to the reflections of the pressure from the surrounding surfaces. In general, the more resistant the walls of the building, the greater the shattering and destructive effect of the explosion. Hence, a building with heavy walls and few windows will in general be damaged to a greater extent than a building with lighter walls and large window areas.

Since the more a high explosive charge is confined during its detonation, the greater will be its shattering and destructive effects, direct hits with even small demolition bombs are immeasurably more destructive than near hits with considerably larger bombs. And particularly is this true when the bomb penetrates into the target before exploding. For this reason, demolition bombs are generally equipped with delay action fuses, which retard the detonation of the explosive charge until after the bomb has penetrated the target. Also, where demolition bombs are to be used against heavy concrete or armored targets, the bomb casing must be strengthened to give it the necessary penetration before explosion takes place. Such heavy-case bombs are generally known as "armor-piercing" and "semi-armor-piercing," depending upon the mechanical strength of the bomb casing.

Fragmentation.—When a bomb detonates, its case is shattered into a large number of fragments which are projected radially from the center of explosion at high velocities (4,000 to 7,000 ft./sec.). If the bomb penetrates a solid target before detonating, the projection of fragments will be reduced in proportion to the depth of penetration and the nature of the material penetrated.

The number and size of the fragments may be determined by exploding the bomb statically in a pit filled with sand packed loosely around the bomb. The fragments are recovered by screening the sand through different-sized screens. A small 30-lb. fragmentation bomb has thus been found to yield about 1,400 fragments averaging 0.27 oz. in weight. Larger general purpose and demolition bombs yield 2,000 to 6,000 fragments, the bulk of which will weigh less than 1 oz. An *effective* fragment is one that will disable personnel. It must weigh approximately 0.2 oz. and be moving with a velocity sufficient to produce 60 ft.-lb. of energy, *i.e.*, a velocity of approximately 500 ft./sec. The distance at which fragments are effective is called their "effective range" or "danger zone."

The velocities of bomb fragments reach a maximum within 10 ft. of the point of explosion and then rapidly diminish, owing to high air resistance, so that at a distance of about 50 ft. from the bomb, the fragments have only approximately half their initial velocities.

When a bomb explodes aboveground in the open, the extreme range of the fragments will vary from about 100 to 1,000 yd., depending upon the size and type of bomb and its density of loading, but the danger zone generally varies from about 200 to 2,400 ft. (see Table II).

When a bomb bursts below the surface of the ground, the crater serves as a sort of crude mortar and projects the blast wave and fragments upward in the form of a conical sheaf. This materially reduces the horizontal effective range of both blast and fragments, and for this reason even an open trench affords considerable protection from exploding bombs (see Fig. 7).

The penetration of flying fragments is dependent on their momentum and the area in contact with the target. In general, the greater the size and velocity of the fragment and the smaller the area in contact with the target, the deeper the penetration. Actual tests have shown that bomb fragments penetrate wood (Douglas fir) 1 to 5 in., depending on the size and velocity of the fragment, the deeper penetration being effected by the larger fragments. The penetration of fragments into other materials of the same general nature will roughly approximate to an inverse ratio with the specific gravity of the material in question.

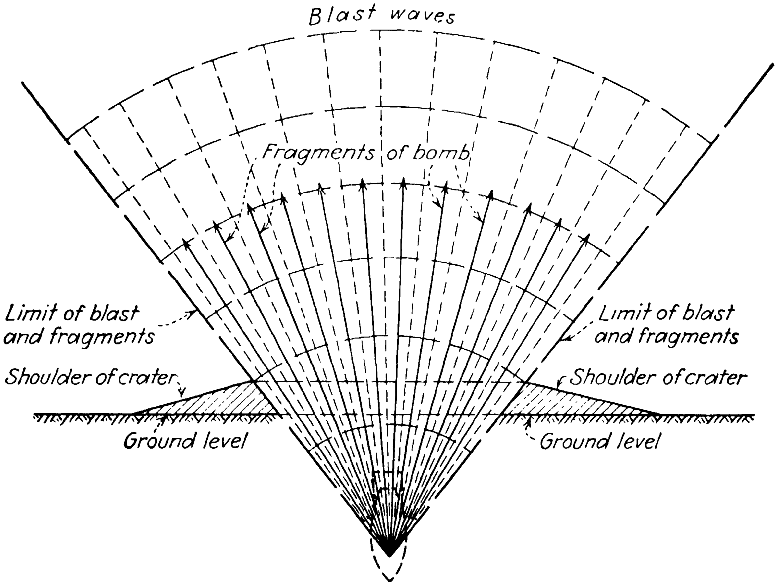
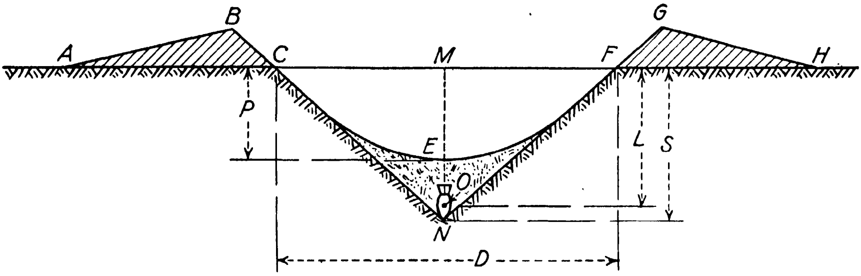


FIG. 7.—Effect of crater on blast wave and fragments.

Owing to the rough and jagged edges of bomb fragments and their erratic paths of penetration, they produce very large and painful wounds which cause a high percentage of deaths and permanent disabilities.

Except in the case of small (30-lb.) fragmentation bombs intended for use principally against personnel in the open, the blast effect of a bomb is, within a limited radius, far more destructive to human life than is fragmentation effect. Moreover, it is much easier to protect personnel from flying fragments than from the effects of blast. Blast being far more important than fragmentation for general destructive effects, general purpose bombs are usually designed with thin casings so as to contain the maximum charge of high explosive.

Cratering.—A falling bomb may burst either on contact with the surface of the target or after it has penetrated to such a depth that the effects of its explosion cannot reach the surface of the target. In the first case, a crater of minimum depth and maximum diameter will be formed; in the second case, no crater at all will appear in the target medium. This latter case is known as a "camouflet"; the only effect of the exploding bomb is to form a spherical chamber of compression in the target medium with compressive stresses in a zone surrounding the compression chamber.



ABC-FGH = Shoulder of crater
D = Diameter of crater = CF
S = Depth of penetration of bomb = MN
L = Depth of burst of bomb = MO
P = Depth of crater = ME
CM/MO = Index of bomb, "n"
ON = Distance of center of gravity of bomb casing to nose of bomb
EN = Depth of loose earth in crater

FIG. 8.—Typical bomb crater in natural earth.

If the bomb bursts sufficiently close to the surface of the target, the force of the gas confined in the compression chamber, acting along the line of least resistance, will break through to the surface, transforming the spherical compression chamber into a crater of conical shape. Normally the line of least resistance is the vertical distance from the center of the explosive charge to the surface of the target.

The size and shape of the crater formed depend upon the depth of penetration of the bomb, the size and character of its high explosive charge, the nature of the medium penetrated, and the energy required to burst the bomb casing. The shape of a typical crater in normal soil (natural earth) is shown in Fig. 8.

From this figure, it will be noted that part of the earth is thrown out of the crater proper and forms a circumferential shoulder around the edge of the crater. This shoulder in effect adds to the depth of the crater but is disregarded in measuring crater depths. Also surrounding the crater is a concentric spherical zone in which the earth will also be cracked and shaken. Within the crater proper, there remains a quantity of loose earth which falls back into the hole after the explosion.

The quantity of loose earth in the crater is proportionately greater as the depth of explosion increases. The ratio of the radius of the crater to the line of least resistance [*CM*/*OM* in Fig. 8] is called the *index* of the bomb and is usually denoted by the letter n. If n equals 1, the bomb is normal; if n is greater than unity, the bomb is said to be *overcharged;* and if n is less than unity, the bomb is *undercharged.* The ratio n usually varies from ½ to 3.

Crater Dimensions.—The dimensions of a bomb crater may be calculated from the following formulas:*

$$C = \frac{S}{10_e} \times L^3 \times (\sqrt{1 + n^2} - 0.41)^3 \qquad (1)$$

where C is the weight of explosive charge, in pounds.

S is the soil factor, depending on the particular soil, (= 1.4 for virgin soil).

e is the explosive factor (see page 27) (usually = 3.0).

L is is the depth of burst, in feet (= OM in Fig. 8).

n is the index of the bomb (varies from ½ × 3).

$$D = 2nL \qquad (2)$$

where D is the diameter of the crater, in feet.

$$p = \frac{L}{3} \times (2n - 1) \qquad (3)$$

where p is the depth of crater, in feet.

Knowing the depth to which a given bomb penetrates a known medium and the weight of the explosive charge in the bomb, we may calculate the value of n from Eq. (1), and by substituting this value in Eqs. (2) and (3) the diameter and depth of crater may be determined.

If the bomb bursts on the surface of the ground,

$$D = 2.5 \sqrt[3]{C}$$

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* "Air Raid Precautions Handbook No. 5 (Structural Defence)," 1st ed., p. 26, His Majesty's Stationery Office, London, 1939.

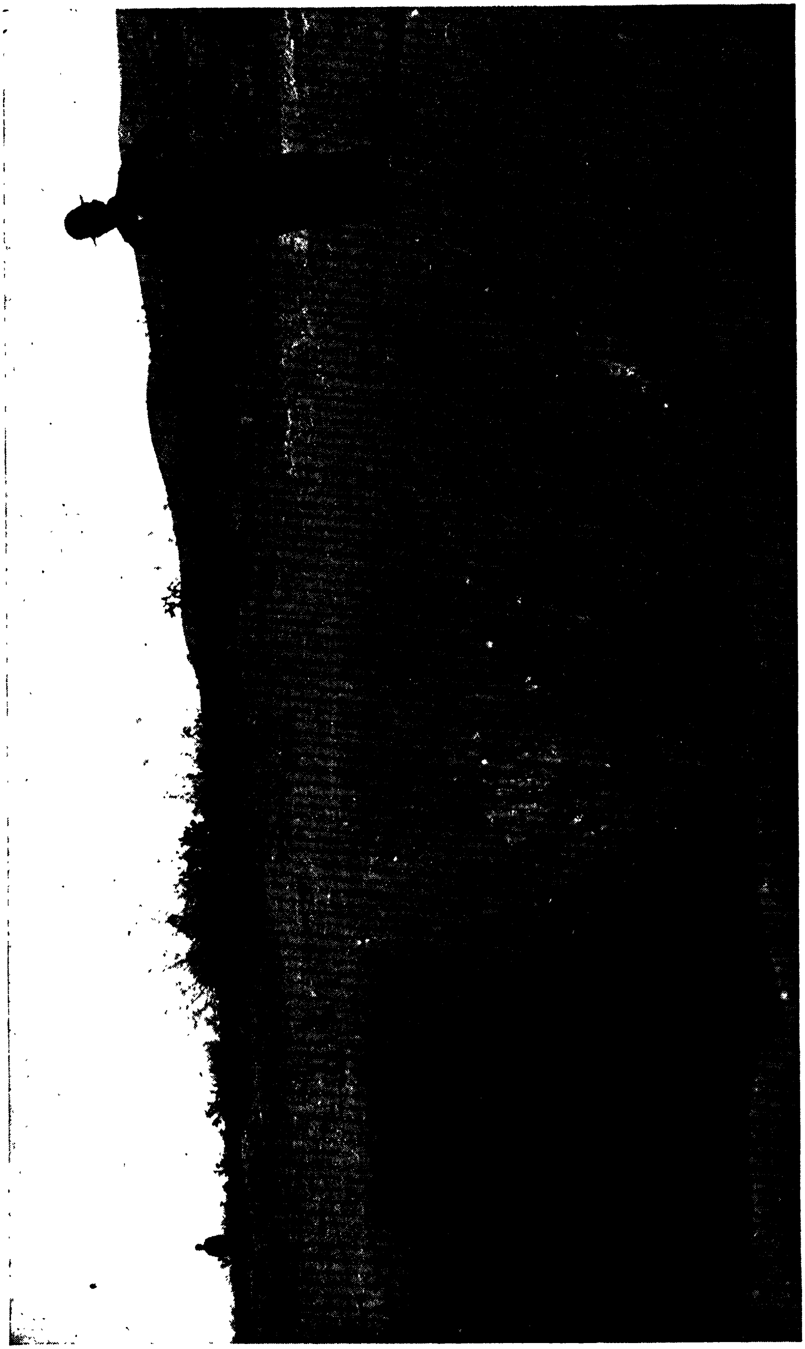


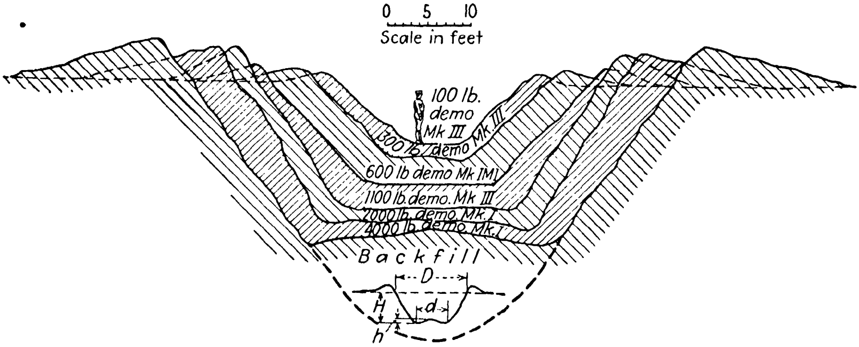
FIG. 9.—Bomb crater of 300-lb. general purpose bomb.

and

$$p = \frac{D}{3}$$

On the basis of the foregoing formulas, the craters produced in natural earth and concrete by typical European and American bombs have been computed and are included in Table II (page 44).

Mining Effect.—In addition to the damage caused by the formation of a crater, a bomb exploding within a solid medium transmits pressure waves through the medium, which are usually accompanied by more or less displacement of the medium surrounding the crater. These pressure waves and the physical displacement of earth are similar to those produced by land mines, and the phenomena are known as *mining effect.* The mining effect of high explosive bombs exploding below the surface of the earth is an important factor in the destruction of buildings by undermining their foundations and in damaging underground utilities, such as water and gas mains and electric power and telephone cables. The distance to which a high explosive bomb bursting underground will exert its mining effect is measured by its horizontal radius and depth of destruction. Fortunately, these distances for even the larger demolition bombs are very limited, so that accurate placement of such bombs is necessary in order to make them highly



BOMB	D FT.	d FT	H FT.	h FT.	CU. YDS. EARTH DISPLACED
100 LB DEMO. MK III	21.8	6.0	6.8	0	42.3
300 LB DEMO. MK. III	27.0	9.3	8.4	0	86.8
600 LB DEMO. MK IMI	38.1	15.2	11.5	0	251.5
1100 LB DEMO MK III	40.5	20.5	14.4	0	403.0
2000 LB. DEMO. MK. I	45.2	24.5	16.5	1.2	600.0
4000 LB. DEMO. MK. I	57.7	29.0	19.0	2.0	1078.0

FIG. 10.—Craters of demolition bombs.

effective. Since the mining effect of a high explosive depends upon its horizontal radius and depth of destruction, it is important to know the radii and depths of destruction of typical bombs in estimating the probable damage to buildings and underground utilities from air attack.

Radius and Depth of Destruction.—The horizontal radius and total depth of destruction of a bomb bursting in the ground may be calculated from the following formulas:*

$$r = \sqrt[3]{\frac{\beta C}{\alpha \delta}} \tag{4}$$

$$H = (h - a) + r \tag{5}$$

where r is the horizontal radius of destruction, in meters (see Fig. 11).

C is the explosive charge, in kilograms.

β is the proportion of the bomb that has penetrated the earth when explosion occurs (see Fig. 11).

α is the "medium coefficient," depending on the medium in which the bomb explodes.

δ is the "tamping coefficient," which varies between 1.0 for good tamping, *i.e.*, when the bomb is completely buried in the ground, to 3.5 for poor tamping, *i.e.*, when there is incomplete penetration of bomb. For ordinary earth, δ may be taken as equal to 0.7.

H is the total depth of destruction by penetration and subsequent explosion, in meters.

h is the depth of penetration of the bomb, in meters.

a is the distance between the center of gravity of the explosive charge of the bomb (*i.e.*, bomb case, less fins) to the nose of the bomb which is presumed to be at a depth h, in meters. For a bomb completely buried in earth, a may be taken as approximately half the length of the bomb case (less fins).

Based on the foregoing formulas, the horizontal radii and depths of destruction in natural earth for typical European and American bombs have been computed and are shown in Table II (page 44).

Radius of Rupture.—In order to ascertain the effects produced on underground structures, such as air raid shelters, by bombs bursting in the near vicinity thereof, formulas, based on mine warfare, have been developed by the British† for determining the shortest distance at which structural damage does not occur to a timbered gallery, from the detonation of an ordinary land mine in the same horizontal plane. This distance is called the maximum horizontal *radius of rupture* and may be taken as the minimum lateral protection that must be provided to ensure the integrity of underground structures from bombs exploding underground in the near vicinity of the structure.

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* HEIDINGER, in *Wehrtechnische Monatshefte*, 1935, **39**, pp. 43–44.

† See "Military Engineering," Vol. IV, Demolitions and Mining, His Majesty's Stationery Office, London.

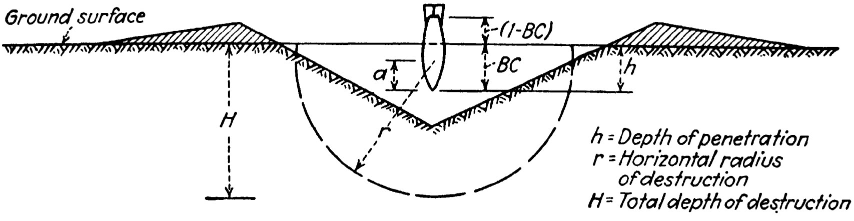
Ground surface
(1-BC)
BC
a
h
H
r
h = Depth of penetration
r = Horizontal radius of destruction
H = Total depth of destruction

FIG. 11.—Radius and depth of destruction.

For practical purposes the following simplified formula is used for determining the maximum horizontal radius of rupture of aircraft bombs:

$$H = F \sqrt[3]{C}$$

where H is the maximum horizontal radius of rupture, in feet.

F is the soil factor, depending upon the target medium (see tabulation below).

C is the explosive charge of the bomb, in pounds.

VALUES OF SOIL FACTOR F

Soil	Factor	Soil	Factor
Hard rock	3.29	Blue clay	6.18
Reinforced concrete	3.30	Loam	6.67
Medium rock	3.87	Gravel	6.83
Soft rock	4.29	Sand, hard	7.59
Hard chalk	4.69	Sand, soft	7.83
Soft chalk	5.42	Made ground, heavy	7.73
		Made ground, soft	9.66

The maximum safe radius of rupture applicable to substantially constructed concrete shelters should be taken as $\frac{2}{3}H$, as computed above.

Total Effect.—The total effects of penetration and explosion of typical European and American aircraft bombs, computed in accordance with the foregoing discussion, are shown in Table II.

Table II
PROPERTIES AND EFFECTS OF HIGH EXPLOSIVE BOMBS

Weight of bomb, lb.	Caliber of bomb, in.	Weight of bomb filling, lb.	Sectional density of bomb, lb./sq. in.	Depth of penetration, ft.		Crater dimensions in earth, ft.		Crater dimensions in concrete, ft.		Radius of destruction in earth, ft.		Horizontal radius of rupture in earth, ft.	Horizontal radius of rupture in concrete, ft.	Danger zone from fragments, ft.
				Natural earth	Reinforced concrete	Diameter	Depth	Diameter	Depth	Horizontal	Depth			
						European Bombs								
	a	*a*	*a*	*a*	*d*	*f*	*f*	*f*	*f*	*g*	*g*	*h*	*h*	*i*
110	7.1	57	2.78	13.7	1.1	27.4	3.4	3.8	0.9	11.0	23.7	25.5	12.6	200
220	9.8	120	2.92	14.4	1.3	28.8	4.8	5.2	1.3	14.0	27.4	32.9	16.3	300
660	14.2	360	4.20	20.7	1.8	41.4	6.9	10.1	2.8	20.2	38.9	47.4	23.5	400
1,100	16.6	600	5.00	24.6	2.1	49.2	8.3	13.4	3.8	23.9	46.5	56.2	27.8	600
2,200	21.6	1,200	6.00	29.5	2.6	59.0	9.8	18.2	5.2	30.2	55.2	70.9	35.1	1,200
4,000	25.6	2,200	7.80	38.0	3.3	76.0	12.7	26.4	7.7	41.8	72.8	86.7	42.9	2,400
						American Bombs								
b	*b*	*b*	*b*	*c*	*e*	*b*	*b*	*f*	*f*	*g*	*g*	*h*	*h*	
100 (120)*	7.9	67	2.13	10.5	0.9	20.0	5.0	3.2	0.7	11.5	22.0	27.0	13.4	200
300 (285)*	12.2	148	2.43	12.0	1.0	27.0	7.0	4.4	1.1	15.0	25.5	35.4	17.5	300
600 (625)*	16.5	349	2.90	14.3	1.2	37.0	10.0	6.7	1.8	20.0	32.4	46.9	23.2	400
1,100 (1,130)*	20.8	632	3.32	16.3	1.4	45.0	13.0	9.0	2.5	24.4	38.4	57.2	28.3	600
2,000 (2,030)*	18.5	1,060	7.55	37.1	3.2	53.0	16.0	22.4	6.4	28.9	61.7	68.0	33.7	1,200

* Actual weight of bomb.

[a] The figures in this column are from M. Bazant, "The Use of Reinforced Concrete for Fortifications and Air Raid Shelters," in *Travaux* Nos. 52 and 53 (April and May), 1937, Tables 2 and 3, for impact velocity of 820 ft./sec., corresponding to a bombing altitude of 13,350 ft. at 200 m.p.h.

[b] The figures in this column are from Technical Regulations 1370-G, War Department, Washington, D.C.

[c] The figures in this column are computed in accordance with formula on p. 30, for impact velocity of 820 ft./sec.

[d] The figures in this column are from Bazant, *loc. cit.*, Table 2, for concrete slab supported over whole of its surface.

[e] The figures in this column are computed from Petry's formula on p. 30, for impact velocity of 820 ft./sec.

[f] The figures in this column are computed from depths of penetration, in accordance with formulas on p. 39 for "normal" bomb ($n = 1.0$).

[g] The figures in this column were computed from formulas on p. 42.

[h] The figures in this column were computed from formula on p. 43.

[i] The figures in this column are from "War on Great Cities," by Frank Morison (Albert Henry Ross), Faber & Faber, London.

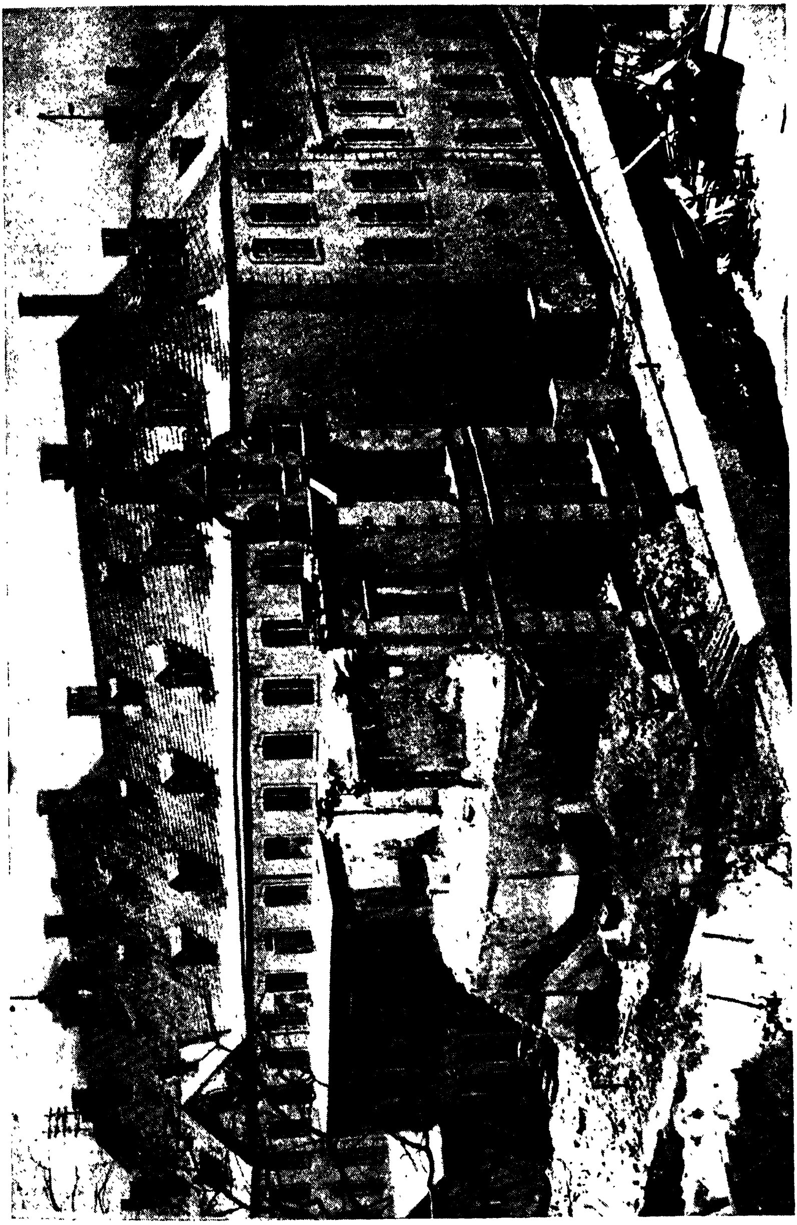

FIG. 12.—Damage to houses from 600-lb. general purpose bomb.

CHEMICAL BOMBS

Types.—Chemical bombs are of two general types, *viz.*, gas bombs and incendiary bombs. Before considering the different types and kinds of gas bomb, it is necessary to understand what is meant by the term "gas," as used in military parlance, and to know the general characteristics of the principal types of war gas.

Definition of Gas.—In warfare a "gas" is any chemical substance, whether solid, liquid, or vapor, that is used in combat to produce physiological incapacitating effects on the human body. War gases are generally liberated in the air as vapors or irritant smokes. They mix with the air and produce their harmful effects upon unprotected persons exposed to this atmosphere by direct chemical action upon surfaces of the body with which they come in contact. In the case of certain gases, such as the so-called "mustard gas," a serious effect is also caused by direct contact of the human body with the liquid chemical or with objects that have become contaminated by the liquid.

Persistency.—From the standpoint of duration of effectiveness in the field, gases are usually divided into two main groups: nonpersistent and persistent. *Nonpersistent* gases are generally volatile substances that quickly evaporate when released from the container. When liberated into the air, these substances form clouds of gas or smoke which drift along with the wind, gradually mixing with larger quantities of air, and thus become progressively more diluted and less dangerous with distance from point of release. Being volatile substances, nonpersistent gases readily evaporate and diffuse into the air, so that, in general, they do not remain in effective concentrations in the open for more than about 10 min. Chlorine, phosgene, and arsenical smokes are examples of nonpersistent gases.

Persistent gases are usually liquids that evaporate slowly, giving off dangerous vapor which moves with the surrounding air to form toxic concentrations. Being nonvolatile liquids, persistent gases remain in effective concentrations in the open for many hours and in cold weather may persist for days and even weeks. As a rough indication of the length of time a persistent gas will remain on the ground, the relative time for complete evaporation, as compared with water, is used. Thus, if water requires 1 hr. to evaporate on open, even ground, in dry weather, lewisite will require approximately 10 hr. and mustard gas 38 hr., under the same conditions.

The ground and other objects on which such liquids have fallen will continue to give off vapor until all the liquid has evaporated or has been rendered ineffective by hydrolysis or neutralizing chemicals. Contact with ground or objects contaminated with certain persistent gases, such as mustard, will cause skin burns until decontamination has been effected. Even walking over such contaminated ground is dangerous and must be avoided unless special protective clothing is available. Mustard gas and lewisite are examples of persistent gases.

Influence of Weather.—Although the effectiveness of a war gas may be considerably influenced by the weather, there are relatively few days suitable for military operations on which gas cannot be effectively used, provided that it is properly employed. At the same time a general knowledge of the influence of weather on gas will materially assist in combating its effects. A high wind rapidly blows away nonpersistent gas and persistent vapors, but it does not remove the danger that results from touching objects or ground contaminated by persistent liquids. Gas is seldom used in winds above 15 m.p.h.

In warm weather, persistent liquids evaporate more rapidly and therefore generate higher concentrations in the air than in cold weather. Hence, in warm weather the danger from persistent gases is greater. On the other hand, temperature has little effect upon nonpersistent gas. In frosty weather, persistent liquids, such as mustard gas, may freeze, but direct contact will still produce skin burns, although there is less danger from vapor. When it thaws, the liquid will again give off harmful vapor. Light rain has little effect upon either class of gas, but heavy rains tend to wash gas out of the air and also help to wash away and destroy any liquid upon the ground.

The most dangerous conditions under which any gas may be used are in mild, calm weather, with or without fog. In the absence of wind, gas diffuses into the air slowly and will therefore drift about in dangerous concentration for a long time. Under these conditions, it may slowly penetrate into buildings through small extraneous openings that have been overlooked.

Physiological Effects.—In addition to the division into two main groups—nonpersistent and persistent—war gases are also classified, according to the effect they produce upon the human body, into the following groups:

1. Tear gases (lachrymators).
2. Lung injurant gases.
3. Vesicant (blistering) gases.
4. Respiratory irritant gases.

Since *tear gases* affect the eyes alone, and then only for a temporary period, they are too mild in action, in comparison with other types of gas, to have much value in future warfare. They need not, therefore, be further considered in connection with air attack.

Lung injurant gases, such as chlorine and phosgene, attack the pulmonary system, causing a burning sensation in the nose and throat and a feeling of suffocation. This is usually followed by edema of the lungs, which may result in death if the exposure is prolonged in a sufficiently high concentration of gas. Since it is readily possible to establish field concentrations of lung injurant gases that will prove fatal to unprotected personnel upon 10 min. exposure and produce serious incapacitation upon even a shorter period of exposure, these gases are among the most dangerous types that may be used in air attacks.

Fortunately, however, lung injurant gases are generally nonpersistent and in usual field concentrations are quite easily protected against by an ordinary gas mask. Hence, there is little danger to personnel in the open air if they are protected by gas masks. It is, however, readily possible for lung injurant gases, when released in confined spaces, to accumulate in very heavy concentrations, which may break through the ordinary gas mask. Hence, the danger of these gases accumulating in buildings damaged by high explosives is very serious.

Vesicant (blistering) gases, such as mustard gas and lewisite, cause irritation or burning of the skin according to the amount of gas that has come in contact with the affected part. No immediate pain is felt on contact with vesicant gas, but the effects become apparent a few hours later.

Vesicants also attack the eyes and lungs, when unprotected by masks, and in such cases there is considerable delay before the symptoms are noticed. This absence of immediate effect and the fact that concentration of gas too weak to be detected can cause incapacitating burns on long exposure constitute two of the greatest dangers from mustard gas. Frequently, the need for protection is not realized until it is too late.

Another outstanding and important factor in the action of vesicant gases is their remarkable power of penetration. Thus, a drop of mustard gas no larger than a match head will go through ordinary clothing and even leather shoes and produce a blister the size of a quarter. This power of penetration is almost universal. Practically the only substances that will withstand it indefinitely are sheets of metal, glass, and highly glazed and resistant materials, such as good-quality tiles or porcelain. Conversely, wood and concrete are readily penetrated by vesicant liquids, and the human body has little or no resistance to them. It is this remarkable power of penetrating all ordinary substances that makes the problem of protection against vesicant gases so extraordinarily difficult.

Respiratory irritant gases are generally produced from arsenical compounds, such as diphenylchlorarsine and diphenylcyanarsine, in the form of smoke. These gases produce intense pain in the nose, throat, and respiratory passages, followed by more or less severe nausea and vomiting. These effects are only temporary and soon disappear in fresh air. They rarely produce incapacitating effects for more than a few hours and for that reason would hardly be used alone in air attacks. As irritant gases are generated in the form of very finely divided smokes, they are remarkably penetrating to gas-mask canisters and require highly specialized filters successfully to remove them from inspired air. They are also effective in extremely low concentrations, ¼ oz. of the chemical per 1,000 cu. ft. of air being intolerable to unmasked men after 1 or 2 min. exposure.

When a man is nauseated by an irritant gas, he will vomit and cannot wear a gas mask continuously, and when he removes his mask he exposes himself to any other gases present. For this reason, irritant smokes will undoubtedly be used in conjunction with other more lethal types of gas, in order to increase casualties. When used in this way, irritant smokes become a serious danger in air attacks, owing to their great mask-penetrative powers and effectiveness in extremely low concentrations. For a further description of the principal World War gases and their properties, see Table III.

Toxic Effect.—The effects of any war gas are in proportion to the amount of gas present and the length of time a person is

TABLE III
PRINCIPAL WORLD WAR GASES AND THEIR PROPERTIES*

	War gas, common name	War gas, chemical name	Persistency (summer)	Lowest irritant concentration, mg. per liter or oz. per 1,000 cu. ft., 10 min. exposure	Lethal concentration, mg. per liter or oz. per 1,000 cu. ft., 10 min. exposure	Boiling point	Vapor density compared with air	Odor in air
Group I. Lachrymators	Bromacetone	Bromacetone (CH_3-$COCH_2Br$)	3 hr. in open; 1–2 hr. in woods	0.0015	3.20	135°C. (275°F.)	4.7	Pungent and stifling
	Brombenzyl cyanide (French, *camite*)	Brombenzyl cyanide (C_6H_5CHBr-CN)	3 days in open; 7 days in woods	0.00015	30 min. exposure, 0.9; 10 min. exposure, 3.5	225°C. (437°F.)	6.6	Like sour fruit
Group II. Lung injurants	Chlorine	Chlorine (Cl_2)	5 min. in open; 20 min. in woods	0.029	30 min. exposure, 2.53; 10 min. exposure, 5.60	−33.6°C. (−28.5°F.)	2.5	Pungent
	Phosgene	Carbonyl chloride ($COCl_2$)	10 min. in open; 3 min. in woods	0.005	30 min. exposure, 0.36; 10 min. exposure, 0.50	8.2°C. (46.7°F.)	3.5	Like ensilage; fresh-cut hay
	Diphosgene (German, *Perstoff;* French, *surpalite*)	Trichlormethyl chloroformate (diphosgene) ($ClCO$-$OCCl_3$)	15 min. in open; 60 min. in woods	0.005	30 min. exposure, 0.36; 10 min. exposure, 0.50 (U.S.); 0.05 (Germany)	127°C. (260.6°F.)	6.9	Disagreeable, suffocating
	Chloropicrin (vomiting gas)	Trichlornitromethane (Cl_3-CNO_2)	1 hr. in open; 4 hr. in woods	0.009	30 min. exposure, 0.80; 10 min. exposure, 2.00	112°C. (231.5°F.)	5.6	Sweetish, like flypaper
Group III. Vesicants	Mustard	ββ-Dichlorethyl sulfide [$(ClCH_2$-$CH_2)_2S$]	24 hr. in open; 1 week in woods	0.001	30 min. exposure, 0.07; 10 min. exposure, 0.15	217°C. (422.6°F.)	5.5	Like garlic or horse-radish
	Lewisite	β-Chlorvinyldichlorarsine (Cl-$CH{:}CHAsCl_2$)	24 hr. in open; 1 week in woods	0.0008	30 min. exposure, 0.048; 10 min. exposure, 0.12	190°C. (374°F.)	7.1	Like geraniums, then biting
	Ethyldichlorarsine (German, *Dick*)	Ethyldichlorarsine ($C_2H_5AsCl_2$)	1–2 hr. in open; 2–6 hr. in woods	0.001	30 min. exposure, 0.10; 10 min. exposure, 0.50	156°C. (312°F.)	6.5	Biting irritant
Group IV. Respiratory irritants	Diphenylchlorarsine (German, *Clark* I)	Diphenylchlorarsine [$(C_6H_5)_2As$-Cl]	5 min by H.E. detonation; 10 min. by candle dissemination	0.0005	30 min. exposure, 0.60; 10 min. exposure, 1.50	383°C. (720°F.)	Practically no vapor. All solid particles	Like shoe polish
	Diphenylcyanarsine (German, *Clark* II)	Diphenylcyanarsine [$(C_6H_5)_2AsCN$]	Same as diphenylcyanarsine	0.0001	10 min. exposure, 1.00	350°C. (662°F.)	8.8	Like garlic and bitter almonds

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* For further description of war gases and their properties, see author's "Chemicals in War," McGraw-Hill Book Company, Inc., New York, 1937.

exposed to it. The stronger the gas, the greater will be the injury produced in a given time. However, even small quantities of most gases will cause injury if the time of exposure is sufficient. In the case of lung injurant gases, a certain quantity must be breathed before it will do any real harm. Hence, the rate of breathing is also a factor here. Thus, a person undergoing hard physical exercise breathes a much greater volume of air per minute than a person at rest, so that, if both were exposed to the same concentration of nonpersistent gas for the same length of time, the former would suffer the greater injury. It is only under exceptional conditions that there is likely to be sufficient gas present in the open air to render one or two breaths dangerous.

Moral Effect.—Finally, the great moral effect produced by gas must always be taken into consideration. Fear of the unknown and unseen always produces a powerful psychological reaction in the human mind, and ignorance of the powers and limitations of war gases may easily produce widespread panic in crowds. This is especially true of the civil population, which is untrained and undisciplined when confronted by emergencies. Napoleon is quoted as saying that in war the moral factor is to the physical as 3 to 1. It is perhaps no exaggeration to add that in gas warfare the moral is to the physical as 100 to 1. Mass education and thorough organization of the civil population are therefore essential to prevent disastrous panics when cities are subjected to air attack and particularly where chemicals are employed in such attacks.

Having surveyed the field of war gases and their powers and limitations, we may now pass to a consideration of the means whereby they may be used in air warfare.

Gas Bombs.—Aircraft bombs are especially adapted for filling with gas because, not having to withstand the shock of discharge from a gun, they can be constructed with a much thinner casing than an artillery shell and thus have a higher useful capacity. The quantity of gas that an aircraft bomb will hold averages 50 to 70 per cent of the total weight of the bomb, as compared with about 15 per cent for the shell. An aircraft bomb, fitted with an instantaneous fuse, is a particularly effective means for disseminating gas because it does not bury itself deeply in the ground and most of the gas is thus liberated on the surface.

Sizes of Gas Bombs.—Gas bombs vary in size from 10 kg. (22 lb.) to 250 kg. (550 lb.), depending largely upon the type of gas filling. In general, the smallest sized bombs (10 kg.) are used for vesicant (mustard) gas, in order to secure maximum distribution. The chief difference between the use of large and small gas bombs is that, for the same bomb load, there will be, in the first case, a few well-marked and heavily contaminated areas and, in the second case, a large number of centers of contamination which will be more difficult to locate and neutralize.

Nonpersistent Gas Bombs.—In the case of a nonpersistent gas, the whole contents of the bomb will form a cloud nucleus near the point of burst, and this cloud will then expand and drift along with the wind. As the gas cloud is swept along with the wind, it becomes more and more diluted with air as its size increases. After traveling a considerable distance the gas becomes diluted with so much air that it becomes harmless. The rate at which dilution progresses depends upon weather conditions, particularly the strength of the wind.

When there is little or no wind, the most dangerous situation arises, although the effects are more localized. A dense cloud of gas forms at the point of burst and remains in that particular area until it is gradually dispersed by diffusion and dilution. Being heavier than air, the gas finds its way by diffusion and ventilation currents into low areas, cellars, tunnels, etc., and once there is not so readily cleared as in open areas. Once the gas has penetrated into a confined space, it is not subject to the influence of wind and air currents prevailing outside and may continue to be dangerous when the outside air is safe to breathe.

Persistent Gas Bombs.—A bomb containing persistent gas (*e.g.*, mustard) makes a large splash of liquid at the place where the bomb strikes and will also cover a considerable area with fine droplets. The degree of contamination and the size of the area infected depend upon the size of bomb, nature of the ground, and strength of the wind. In hard ground the penetration is slight, and the liquid is more widely distributed over the surrounding area. Again, if the wind is fairly strong, the drops formed by the explosion of the bomb may be carried down-wind for a considerable distance.

Anyone near the spot where the bomb strikes will be contaminated by the liquid drops and must take immediate action to avoid injury. Persons walking over gas-contaminated ground will be liable to injury from stepping in the liquid or even from adhering mud containing mustard gas, since mustard readily penetrates through ordinary leather shoes. This danger may persist for several days unless the area is decontaminated or closed to prevent movement over it. A dangerous concentration of persistent gas vapor may also travel down-wind in exactly the same way as a cloud of nonpersistent gas, although it usually is not effective for the same distance.

Respiratory Irritant Gas Bombs.—In developing bombs filled with respiratory irritant gases (arsenical smokes), it is probable that such gases will be produced by some form of generator contained in the bomb, since such gases are most effective when disseminated by thermal distillation. In this case the gas cloud will be emitted for some minutes from the place at which the bomb falls, and the distance to which the gas travels in an effective concentration may be considerably greater than with other nonpersistent gases, owing to the extremely low concentrations in which respiratory irritants are effective.

Gas Sprays.—The most recent method of disseminating gas from aircraft is by spraying. Owing to evaporation losses, only the persistent gases can be effectively sprayed and then only from relatively low altitudes. When persistent gases, such as mustard, are sprayed from aircraft, the liquid falls in fine droplets over a fairly large area. Thus, a single attack-type of plane, under favorable conditions, can cover with an effective concentration of mustard gas an area 1,000 yd. long and 200 to 300 yd. wide, and a light bombardment plane can cover an area of twice this size.

The liquid droplets falling from an airplane spray may indeed be so small that they are not noticed at all by persons upon whom they may fall. Hence, such a spray is a source of very great danger, because it may fall directly on the face, neck, and any exposed parts of the body, without being noticed. The risk to persons in the open is thus obvious, but the danger may be largely avoided by remaining under cover.

Gas and High Explosive Bombs.—Probably the greatest danger from an air attack is when gas is used in conjunction with high explosive bombs. The shattering effects of high explosive bombs will usually destroy even the best gas-proofing in buildings, thus admitting the gas to the interior of the building, where it can accumulate in maximum concentration. Also, material damage will be caused by the high explosives; and the gas (especially mustard), whether used in bombs or sprays, will render the task of rescuing and treating casualties much more difficult and hazardous.

Incendiary Bombs.—The remaining type of chemical bomb to be considered is the incendiary bomb. These bombs may be of any weight from 1 kg. (2.2 lb.) to 20 kg. (55 lb.), or even more. Several types and sizes have been tried out in recent years by different countries, but the design that has proved most successful to date is a bomb commonly called in Europe an *electron* bomb, weighing 1 kg. and consisting of a thick-walled magnesium tube, filled with a mixture of powdered aluminum and iron oxide, called "thermite" (see Fig. 13).

When this bomb strikes, the composition is ignited and burns fiercely at a temperature of about 3,000°C. for about 1 min., melting and setting fire to the magnesium casing. The molten magnesium, which is the principal danger, burns for 10 to 15 min. and will set fire to anything inflammable within several feet. During the first minute, while the priming composition is burning, the bomb reacts very violently; jets of flame are emitted from vent-holes, and pieces of molten magnesium may be thrown as far as 50 ft. The thermite composition contains its own oxygen and so cannot be extinguished by water or smothering, but the magnesium must get its oxygen from the air or surrounding materials in order to burn.

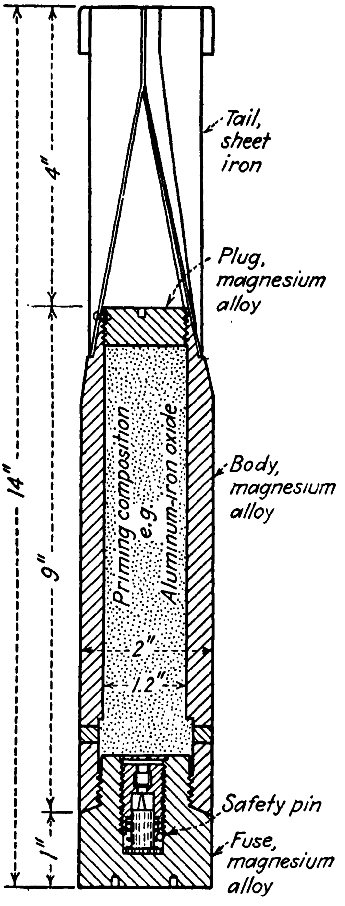

FIG. 13.—One-kilogram magnesium (electron) incendiary bomb.

One large bomber can carry between 1,000 to 2,000 of the very light incendiary bombs, the number depending upon the weight of gasoline carried. They are generally dropped from high altitudes, since they do not attain their maximum velocity and penetrative power until they have fallen about 5,000 ft. The bombs are usually dropped from containers, each holding 10 or 20 bombs, and the contents of several containers can be released simultaneously. The bombs spread out as they fall, and a group dropped simultaneously from 5,000 ft. covers an area of about 100 yd. square. As these small bombs have very poor ballistics, they cannot be aimed accurately, but precision is not essential in this case. All that is necessary is that the bombs cover the target area generally.

Effect of Incendiary Bombs.—The 1-kg. electron bomb, falling from 5,000 ft., will penetrate normal roof construction and a plaster ceiling below the roof but is unlikely to penetrate the first floor below. If not immediately extinguished or removed, the bomb may burn through a wooden floor and possibly through further surfaces, causing a succession of fires in the building.

The number of fires that may be started simultaneously cannot be precisely estimated, but the following calculations will give some indication of what might be expected: In large towns in this country the average proportion of open spaces to built-up areas may be taken as about 4 to 1, or about 20 per cent built over. Accordingly, for every 5 bombs dropped, 1 may be expected to hit a building, and the remaining 4 to fall in streets, gardens, yards, etc., where they would burn themselves out without doing any serious damage. Supposing, therefore, that a single bomber carrying 1,000 bombs has reached such a town, 1 hit in 5 would mean about 200 hits. But, of these, about half either might glance off sloping roofs and not penetrate or, penetrating, might fail to function. The remaining 100, or approximately 10 per cent of the bombs dropped, would probably cause fires. The size of the area in which these fires may occur would depend upon the speed at which the bomber was flying, how quickly the bombs were released, and the height from which they were dropped. For instance, flying in a straight line, at 200 m.p.h. at a height of 5,000 ft. or over, and releasing 20 bombs per second, the bomber would drop its 1,000 bombs in a little under 3 miles and would start 1 fire every 50 yd. In practice, there is little doubt that attacks would be made by squadron formations, which means, of course, that the number of fires would be multiplied by the number of planes in the squadron.

Larger Sized Electron Bombs.—Since the main object of an attack with incendiary bombs is simultaneously to start more fires than can be dealt with by the fire-fighting services normally available in a community, this result can best be achieved by dropping the greatest number of the smallest sized bomb that can be relied upon to initiate a fire. The 1-kg. (2.2-lb.) electron bomb fulfills this requirement for ordinary houses and the more flammable of industrial buildings. For the more fire-resistant type of structure, larger bombs of similar type are likely to be used, and 2-, 12-, and 25-kg. sizes of electron bombs have been developed for this purpose. Although the 2-kg. bomb might be used for general incendiary bombing, it is probable that the larger sizes would be reserved for special targets of unusual military importance. Except that the larger electron bombs will penetrate through several floors of a wooden building, they differ from the 1-kg. sized bomb not in effect but only in degree.

Multiple-unit Electron Bombs.—In addition to the single-unit types of electron bomb mentioned above, there has also been developed a special multiple-unit type of electron bomb for use against certain kinds of target, such as storehouses, large factory buildings, and ammunition storage yards. These bombs usually have a minimum weight of 12 kg. (26 lb.) and consist of a casing containing a number of separate incendiary units. The casing is provided with a steel nose to enable it to penetrate a strongly constructed roof. After penetration the bomb bursts and expels the incendiary units over a relatively wide area. Each unit functions as a separate small incendiary bomb and may initiate a fire wherever it falls. Since each unit is substantially the same as a small (1-kg.) incendiary bomb, it has about the same igniting effect, although it does not possess the same penetrating power as the single-unit 1-kg. bomb.

Other Types of Incendiary Bomb.—Although the electron type of incendiary bomb is by far the most effective in general use today, other kinds of incendiary bomb have been used during and since the World War and may be encountered in future warfare.

Fundamentally, thermite and magnesium, which are used in the electron bomb, are by no means the best materials for generating heat. Other materials, such as petroleum, pitch, phosphorus, and sodium, on burning, liberate a much greater quantity of heat than thermite; and petroleum, in particular, generates nearly twice as much heat per gram as magnesium. The amounts of heat generated per gram by these materials are as follows:

Material	Heat Generated, Gram Calories
Petroleum (average) (gasoline and fuel oil)	11,000
Pitch	8,400
Magnesium	6,000
Phosphorus	5,900
Sodium	2,200
Thermite	800

All the materials above were used, with the possible exception of magnesium, as incendiary agents, either singly or in combination with each other, during the World War. Although they all greatly exceed thermite as heat generators, they have other properties that militate against their effectiveness as incendiary agents. Thus, petroleum is not suitable for use in small incendiary bombs on account of its light weight. A 1-kg. bomb, filled with gasoline, for example, would contain less than 1 pt. of fuel, and its heat value when spread over an area would be relatively small. Also, the incendiary effect of petroleum is almost entirely upward, and quite a large quantity can be burned on a wooden floor without more than scorching it. Again, phosphorus burns rather slowly, with a very cool flame. It also melts and forms a coating over the material with which it is in contact and renders it less combustible. It is, therefore, not a very good incendiary agent, although it was extensively so used during the World War.

Sodium and potassium, both in pure and alloy forms, were used to some extent as incendiary agents in the World War, chiefly in artillery shells. Although they react vigorously with water and generate enormous quantities of heat, they do not function very effectively as incendiaries against dry materials. Their chief use would probably be in conjunction with one or more of the other incendiary agents mentioned above, to prevent quenching with water, since violent explosions are apt to result when attempts are made to extinguish such mixtures with water.

All in all, thermite proved to be the best incendiary agent used in the World War because of its high temperature of combustion and intense localized heat production. The greatest improvement in the development of incendiary agents since the World War has been the addition of magnesium to the thermite filling. This combination greatly exceeds either material alone in its incendiary effect and appears to be by far the most efficient fire producer of any material yet discovered. In view of the immense amount of development work that has been performed in the field of incendiaries during and since the World War and the well-known limitations of other materials as incendiary agents, it is not likely that anything other than thermite and magnesium, in combination, will be used until some new compound is developed and found to be more effective.

Having considered the various weapons with which air attacks may be made, we may now estimate the situation as to their probable employment in war and the resulting effects on the civil population.

Choice of Weapons.—At the outset, it is obvious that the choice of weapons to be used in any military operation depends: (1) upon the purpose of the operation and the results expected to be achieved thereby; (2) upon what may be termed the belligerent's "philosophy of battle"; (3) upon the relative efficiencies of the several weapons to attain the desired results. We shall briefly consider these three factors in the order mentioned.

Objectives of Military Attack.—Irrespective of whether or not the grand strategy of war still regards hostile armies in the field as the primary objective of a nation's military effort, it is becoming increasingly evident that ability to wage war is to be measured by munition producing capacity, rather than armed man power. Hence, any means that will effectively cripple a nation's industrial economy generally, and its munitions industry specifically, will be a powerful aid to ultimate victory.

Role of Air Power.—Owing to the ability of air power to strike suddenly and directly at an enemy's industrial areas, wherever located (within the effective radius of bombing planes) and regardless of how strongly that nation's frontiers may be guarded by land and sea, aviation is the means, par excellence, for carrying out such missions. Moreover, since industrial plants, transportation and communications systems, munitions of all kinds, and even food supplies may be regarded as legitimate military objectives and since the most important concentrations of these instrumentalities occur in the large cities, it seems inevitable that these cities will be the logical targets for air bombardment. And this is true even if the aggressor state adheres to the doctrine of the military objective and makes no attempt to bring pressure upon the government of the opposing state by direct attack upon its civil population.

This being the case, it seems equally clear that, regardless of whether the aggressor state adopts the Douhet theory of direct air action or the traditional military field army theory of war, a considerable part of its air strength will certainly be employed against its opponent's industrial centers in large urban communities.

Purpose of Air Attack.—Now, if the purpose of an air attack is to destroy industrial *property*, the use of gas as a possible weapon is eliminated, except perhaps a very limited use of persistent gas in conjunction with high explosive bombs to obstruct and retard rescue and repair work. The choice of weapons for the destruction of property by air attack, therefore, lies between high explosive and incendiary bombs and depends largely upon the nature of the buildings and structures to be destroyed.

If the targets to be destroyed are strong, massive structures of fireproof materials, such as concrete and steel factories, warehouses, wharves and docks, bridges and dams, and shipyards and powerhouses, it is obvious that incendiary bombs would be useless and only heavy demolition bombs would be effective. On the other hand, against ordinary frame structures, buildings of mixed wood and brick construction, illuminating gas plants, oil storage tanks, etc., both high explosive and incendiary bombs would be effective, but the latter would generally be more efficient in destroying large areas because of their more extensive coverage. We have seen that a medium bomber, carrying a thousand 1-kg. incendiary bombs, can cover a strip approximately 3 miles long, with fires initiated at 50-yd. intervals and that a single squadron of 18 such planes could thus set fire to an area 1 mile wide and 3 miles long. On the other hand, the same bomber, carrying twenty 50-kg. or ten 100-kg. general purpose high explosive bombs, could damage buildings in only 10 to 20 spots in its flight over the target area. These spots would be very limited in extent; for a 50-kg. high explosive bomb has a radius of destruction of only 11 ft., with a danger radius of 100 ft., and a 100-kg. high explosive bomb has a radius of destruction of 13 ft., with a danger radius of 125 ft. There is, of course, the additional possibility that a lucky hit with a high explosive bomb might start a fire; but, as a rule, high explosive bombs are not efficient for this purpose.

If, however, the purpose of an air attack is to paralyze munitions work or cripple industrial production, by action against working personnel, gas is far more efficient than either high explosives or incendiaries, particularly when accompanied by a percentage of high explosive bombs to invalidate the gas-proofing of factory buildings and shelters. Modern factory buildings are generally more or less fireproof, and they can readily be protected against damage from high explosive bombs, except the localized effect of direct hits. On the other hand, gas in bombs and sprays will contaminate the whole working area and will cripple production far more seriously by its demoralizing and casualty effect upon the working personnel. For this purpose, persistent vesicant gases (*e.g.*, mustard and lewisite) are agents, par excellence, for they have tremendous coverage, great penetrative and contaminating power, and widespread, though seldom fatal, casualty effect.

Effect of Air Gas Attack.—One medium bomber, carrying a hundred 10-kg. mustard bombs, can create in one flight over a target area 2 to 3 miles long 100 centers of contamination, each approximately 40 yd. in diameter. This means a total contaminated area of 126,000 sq. yd., or the equivalent of about five average city blocks, from each bomber. *Every* person in this area not completely protected by a gas mask and adequate protective clothing may become a serious casualty, unless he is immediately removed to an uncontaminated atmosphere; and, even if promptly removed, unprotected persons will probably sustain some incapacitating effects.

In congested urban communities, an average of 20 out of every 100 bombs dropped at random will strike a roof and explode inside a building. In each such case a very serious situation arises, for each bomb contains sufficient mustard gas to contaminate everything in a building 120 ft. long by 100 ft. wide. Aside from the fact that all unprotected persons in the building would undoubtedly be more or less seriously gassed, the building would be dangerous for occupancy for several days, even if decontamination work were attempted, because of the difficulty of decontaminating wood and concrete walls, floors and ceilings, and the intricate surfaces of machinery, etc.

This very serious indoor effect of persistent vesicant gas is generally overlooked by writers in comparing the relative effects of high explosives and gas in air bombardments. They seem to concern themselves only with the gas that falls in the street and on open ground and point out how easily such gas may be avoided by going indoors and closing all windows and doors until the gas has evaporated or is neutralized by decontamination. This is, indeed, the least serious effect of gas bombing or spraying, for gas on the open ground is most quickly dissipated and most easily neutralized by decontamination. Far more serious is the persistent gas that adheres to roofs and sides of low buildings, where it is difficult to reach and neutralize and is sufficiently close to spread serious concentrations of vapor. And most serious of all is the gas that is liberated indoors, as indicated above.

Another point frequently ignored by optimistic writers who count heavily on the protection furnished by closed buildings is the fact that in summer it is frequently impossible to occupy buildings completely closed up for any length of time. Also, by using a percentage of high explosive bombs in gas attacks, windows and doors are blown open, and gas will thus find its way into buildings that would otherwise be fairly gas-tight.

What has been said above concerning the effect of persistent vesicant gas also applies more or less to nonpersistent gas. Although the casualties are more serious with nonpersistent gas, the coverage per pound of chemical is very much less and its persistence is measured in minutes instead of hours and days. For these reasons, it is improbable that nonpersistent gas would be used to any great extent in air attacks on industrial plants.

On the other hand, if the policy of the aggressor state is to apply pressure to its opponent's civil population by direct air action, in accordance with the Douhet doctrine of unlimited warfare, it is probable that nonpersistent gases would be used in large quantities in surprise attacks on the great cities. Large-scale attacks with nonpersistent gas would produce the most serious casualties and maximum demoralization among the civil population in large congested cities. And especially would this be the case if the cities attacked were not fully prepared to meet such attacks by thorough organization, training, and equipment of its citizenry.

Large-scale attacks with nonpersistent gases, such as phosgene with arsenical smoke, apply the severest test to anti-gas protective systems and cause the greatest strain on the morale of the people. When such gas attacks are accompanied by high explosive bombs to impair the anti-gas protection of buildings, widespread casualties and general demoralization of the community are apt to result from the immediate effects produced by these gases.

Figure 14 shows the comparative areas covered by the same weight of incendiary, high explosive, and gas bombs. One average bomber can carry a bomb load of about 1,000 kg. (2,200 lb.). This is equivalent to a thousand 1-kg. incendiary bombs, four 250-kg. high explosive bombs, or four 250-kg. gas bombs. From Fig. 14 it will be noted that 250 one-kilogram incendiary bombs will cover an area about 1,300 yd. long by 100 yd. wide and will cause an average of 25 fires at 50-yd. intervals in this area. One 250-kg. high explosive bomb will create a crater of 6 yd. radius in average soil, will rupture the earth to a radial distance of 15 yd., will exert a blast effect to a radial distance of 33 yd., and will throw fragments to a distance of 67 yd. A 250-kg. nonpersistent gas bomb will splash a circular area of 25 yd. radius and will cover a circular area of 75 yd. radius with a *lethal* concentration of 1 to 10,000 and a circular area of 167 yd. with a dangerous concentration of 1 to 50,000, provided that no wind is blowing. With a wind blowing, the lethal area will extend down-wind for a distance of 600 yd., and the danger area to a distance of 1,000 yd.

Under favorable conditions, one medium bombardment plane, carrying four 250-kg. phosgene bombs, can establish a concentration that is deadly on 10 min. exposure over four circular areas, each about 300 yd. in diameter. At this rate a squadron of 12 planes in one flight could cover 1 square mile with a deadly concentration of gas, so that every *unprotected* person exposed for 10 min. would become a very serious casualty and over half of them would die. In addition to this deadly area the gas would be carried down-wind in gradually diminishing strength and would cover an additional area of equal size with a concentration sufficient to cause less serious, nonfatal casualties.

Even if this additional danger area be disregarded, a large city, such as New York City (area 300 square miles), could *theoretically* be covered with a deadly concentration of phosgene with a total of 3,600 medium bombers. Of course, it is highly improbable that air gas attacks on any such colossal scale would ever be attempted, but it is entirely possible that the congested business districts of the larger cities would be so treated, and only the most thorough preparations to counter such attacks would prevent panics and major disasters.

Persistent vesicant gases, in large numbers of small bombs or in sprays, would also prove very serious against the congested districts of the large cities. Although that portion of the spray which falls on roofs of multistory buildings will be largely evaporated into the upper air and therefore ineffective for producing casualties, it must be borne in mind that, in an average city in this country, four-fifths of the city area is streets and open ground, so that 80 per cent of the gas would reach the ground. Also, since bombs and

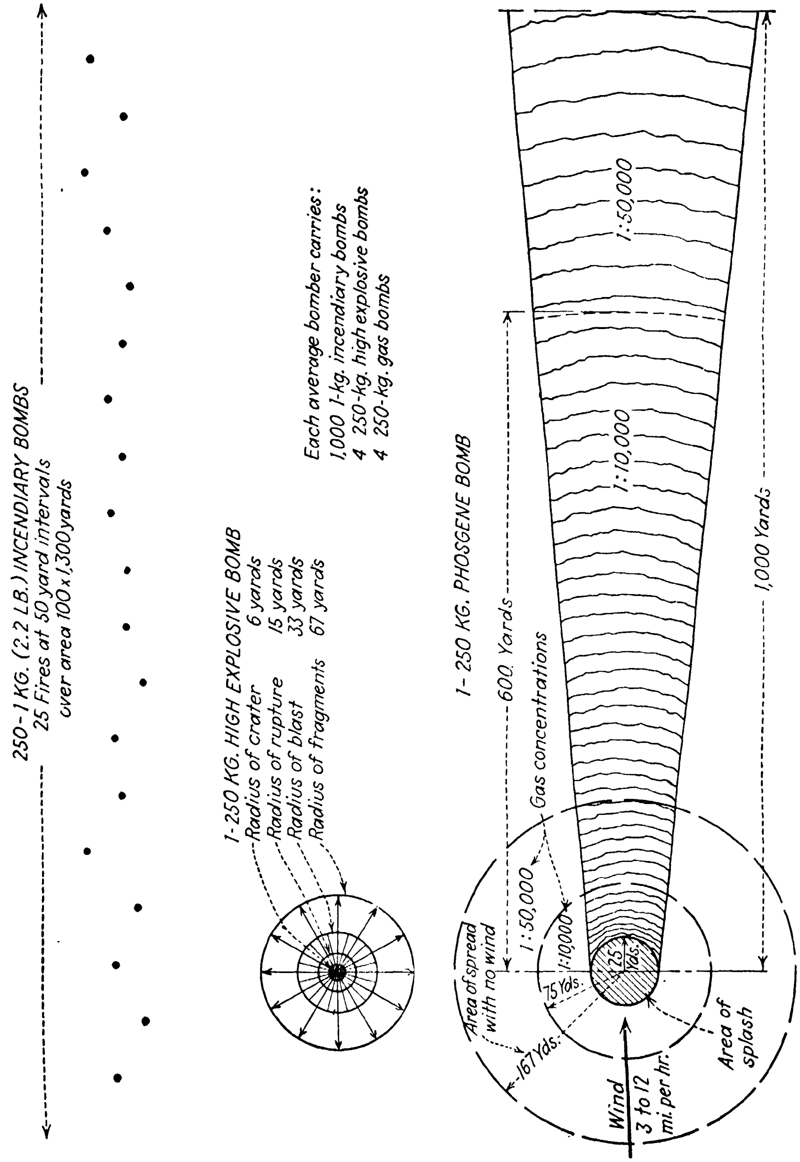
250-1 KG. (2.2 LB.) INCENDIARY BOMBS
25 Fires at 50 yard intervals
over area 100 x 1,300 yards
Each average bomber carries:
1,000 1-kg. incendiary bombs
4 250-kg. high explosive bombs
4 250-kg. gas bombs
1-250 KG. HIGH EXPLOSIVE BOMB
Radius of crater 6 yards
Radius of rupture 15 yards
Radius of blast 33 yards
Radius of fragments 67 yards
1-250 KG. PHOSGENE BOMB
600 Yards
Gas concentrations
1:50,000
1:10,000
1:50,000
1:10,000
25 Yds.
75 Yds.
167 Yds.
Area of spread with no wind
Area of splash
Wind 3 to 12 mi. per hr.
1,000 Yards

FIG. 14.—Danger areas of bombs.

spray fall not vertically, but at an angle, an appreciable percentage would strike the sides of the buildings and thus set up centers of contamination that could not be readily reached by decontaminating means.

Though it is true that war gases do not ordinarily rise aboveground more than a few feet, the spray and droplets from bursting bombs may be carried considerably higher by the wind, and the contaminated roofs and sides of the buildings would also contribute a certain amount of dangerous vapor above the ordinary level of gas in the street. Nevertheless, if windows and doors are kept closed, rooms on the third and higher floors aboveground would be relatively safe for several hours against dangerous concentrations of gas and are therefore the best natural refuges in gas attacks. For this reason, large metropolitan centers, with many tall buildings, like New York, are, on the whole, the safest in gas attacks, provided, of course, that the people are calm and know what to do.

The great danger in relying on ordinary buildings for protection against gas is that it is probable that high explosive bombs will be used in conjunction with gas in air attacks and that, therefore, many windows and doors would be so damaged as to afford a ready entrance for gas into the building. Once inside, gas does not readily dissipate by diffusion and dilution with air but tends to collect in high concentrations and to linger longer than outdoors. Also, it is possible that the ventilating systems in many large office buildings would actually increase the circulation and spread of the gas throughout the buildings.

But perhaps the greatest danger from air gas attacks on the great cities is the element of surprise, which will result in large numbers of people being caught in the streets and open spaces without any form of protection. With the technique of silent approach, and under cover of darkness and thick weather, there now appears to be little to prevent air attacks being delivered with great suddenness and surprise.

Concerning the effect of air gas attacks on the great cities, it is interesting to note the following view of an eminent British military authority, General J. F. C. Fuller, as set forth in his book "The Reformation of War":

> I believe that in future warfare great cities, such as London, will be attacked from the air—and that a fleet of 500 airplanes, each carrying 500 ten-pound bombs of, let us suppose mustard gas, might cause 200,000 minor casualties and throw

> the whole city into panic within half an hour of their arrival. Picture, if you can, what the result will be: London for several days will be one vast raiding bedlam, the hospitals will be stormed, traffic will cease, the homeless will shriek for help, the city will be a pandemonium. What of the Government at Westminster? It will be swept along by an avalanche of terror. Then will the enemy dictate his terms, which will be grasped at like a straw by a drowning man. Thus may a war be won in forty-eight hours and the losses of the winning side may be actually nil!
>
> But it will naturally be asked: How about air defense? Local defense is, even in the best weather conditions, but a palliative, and in conditions which favor aerial action, quite useless.
>
> But, it will be argued, no civilized state would now resort to such barbaric measures. Even if prepared to disregard humane considerations, it would be deterred by the knowledge that such conduct would antagonize world opinion. But I would point out here that the belligerent possessing an overwhelming striking force need not necessarily resort to wholesale slaughter and destruction in order to gain his end. He might bring sufficient pressure to bear upon the enemy people by employing a non-lethal gas. Or he might combine non-lethal gas attacks with incendiary bombs, thus starting widespread conflagrations, which, while increasing the moral effects of his blow, would also cause immense material destruction.

Despite its undoubted efficacy in producing widespread casualties and demoralization among the civil population in the great cities, it may be seriously doubted that gas would be so used, except as a last resort, by any responsible government, for fear of retaliation if for no other reason. The use of gas is indeed a two-edged sword which may cut equally well both ways, and the certainty of reprisal on its own citizens will undoubtedly restrain any belligerent state from embarking upon unlimited gas warfare from the air, unless it is in desperate circumstances and is willing to gamble all on one gigantic blow, in the hope of crushing its adversary before he can retaliate.

Although the use of gas against the civil population, at least in the early stages of a war, may be considered as unlikely, nevertheless, there is always the ever-present danger that it may be used at any time and may come as a complete surprise. For this reason, the only safe course that any government worthy of the name can adopt is to see that all possible steps are taken in time of peace to prepare for such an eventuality and that its civil population will be adequately protected against such attacks. It is in recognition of this danger that each country in Europe has provided gas masks and shelters for its entire urban population and has set up a most elaborate system of Passive Defense in its great cities.

CHAPTER III

DEFENSE AGAINST AIR ATTACK

General Principles of Air Defense.—The three-dimensional space in which air forces operate is so vast in comparison with the two-dimensional area in which armies and navies function and the speed of aircraft is so much higher than that of the fastest land or seacraft that the time and space factors of air combat are of an entirely different order of magnitude from those of land or naval warfare.

Unlimited space and high speed greatly increase the power of air offense as compared with the power of air defense. In land and naval warfare, it is generally assumed that an attacking force must be larger and more powerful than the defending force in order to succeed, and it usually is impossible for an attacking army or navy to attain its objectives until it has defeated the defending forces. In the air, however, these conditions do not obtain, for it is quite easy for an attacking force completely to elude or slip past a vastly superior defending air force and reach its objectives with but relatively minor losses. Aside from space and speed, there are other means of eluding a defending air force that greatly favor the air attack, chief among which are: darkness, fog, low cloud ceiling, and artificial smoke blankets laid by attacking aircraft themselves. It is axiomatic that attacking airplanes cannot be stopped unless they can be seen by the defending forces in the air and from the ground. Hence, conditions such as those mentioned, which favor concealment of approaching airplanes, powerfully aid attacking aircraft to elude or break through the defense.

Fundamentally, the best way to stop a hostile air attack is completely to forestall it by destroying the enemy air fleet on the ground. This is the strategy behind the raids on airdromes and flying fields and is the task of bombardment aviation. However, this form of action can never be 100 per cent effective, for airdromes are now placed underground where they are hidden from view of attacking aircraft and are provided with sufficient bombproof cover to resist heavy air bombardments, and flying fields are widely scattered and skillfully camouflaged, so that it is almost impossible to find and destroy them. In addition to these difficulties, airdromes and flying fields are generally heavily defended by antiaircraft guns which keep attacking bombers at high altitudes and thus increase the difficulty of locating and hitting them.

Next to the destruction of hostile air forces at their bases, the most effective means of preventing an air attack is to intercept and destroy the attacking force before it comes within striking distance of its objective. This is the mission of intercept and pursuit planes, generally termed "fighters." The fighters thus constitute the outer ring of Active Air Defense.

Once an invading air force has come within range of its objective, it is opposed by antiaircraft artillery and machine gun fire. The mission of this fire is to disorganize the attacking force by shooting down the bombers before they reach the bomb release line or, at least, to cause them to fly so high and in such irregular paths as largely to nullify effective bombing. The antiaircraft artillery and machine guns thus constitute the inner ring of Active Air Defense.

Another means of Active Air Defense, which is particularly aimed at low-flying attack planes, is the balloon barrage. This consists in a large number of captive balloons, arranged at close intervals in concentric circles around the target area to be defended, in such manner as to intercept low-flying aircraft when approaching the defended area.

A valuable auxiliary to Active Air Defense is the antiaircraft searchlight whose mission it is to illuminate hostile aircraft within the vicinity of the defended area so that they can be seen and attacked by defending fighter planes and antiaircraft artillery. Searchlights are placed in a manner similar to captive balloons and are under the control of the antiaircraft artillery commander.

In order to alert the various elements of Active Air Defense and enable them to be brought into action in sufficient time to be effective, it is necessary that they have ample warning of the approach of hostile aircraft. This is the mission of the Aircraft Warning Service which consists in a large number of observers, stationed at posts spaced at intervals of not more than 8 miles apart over the whole area to be defended and out as far as possible in the direction of attack.

These observers are in telephone or radio communication with a series of information centers which receive, plot, and evaluate their reports and then notify defending air forces and antiaircraft artillery units whenever it appears that hostile aircraft are approaching their areas.

Although the Aircraft Warning Service operates under the direction of the Chief of Air Defense and is usually considered an element of the Active Air Defense, it also serves to warn civilian communities and industrial establishments of the approach of hostile aircraft so that the various measures of Passive Defense may be put into effect in ample time. The Aircraft Warning Service thus serves both Active and Passive Defense and may be regarded as the connecting link between the two.

When all means of Active Defense have failed to prevent hostile aircraft from reaching their objective, it is the mission of Passive Defense to counter the consequences of the attack, by every available means, with a view to preventing the loss of life and limb, limiting the destruction of property, particularly establishments vital to the national defense, forestalling mass hysteria and panic, and, above all, maintaining public morale. Passive Defense is a responsibility of the civil authorities and operates under their direction and control. Before adverting to the various means and methods of Passive Defense, we shall first consider the powers and limitations of the various elements of Active Air Defense.

Active Air Defense.—We have seen that, aside from the bombardment of enemy airdromes and flying fields, the outer ring of Active Air Defense consists in the intercept and pursuit (fighting) planes, whose mission it is first to contact approaching hostile bombers and then to prevent them from reaching their objectives.

Fighting aircraft are characterized by their small size, high speed and maneuverability, great climbing power, and relative short cruising range. They are generally equipped with multiple machine guns and in a fire fight are supposed to have the advantage over the bombing planes by reason of their greater speed and maneuverability. In recent years, however, the speed of the bombers has been so markedly increased that the defensive fighters no longer enjoy their former margin of speed. Also, with bombers flying at 300 m.p.h. and the fighters at anything up to 400 m.p.h., it has become increasingly difficult to secure effective hits with machine guns, and the task of the fighter is much more difficult than was formerly the case. For this reason, some of the most recent fighting planes are being equipped with light rapid-fire cannon.

An even greater difficulty for the defensive fighters in preventing bombers from reaching their objectives is the greatly increased altitude at which the bombers can now fly and the ease with which they can elude discovery by the defensive air force. Modern bombers can readily fly at altitudes of 30,000 ft. or more and are then completely invisible from the ground, even in broad daylight. On clear days, aircraft are practically invisible from the ground when flying above 18,000 ft., and the altitude at which they may be seen from the ground steadily decreases with adverse visibility conditions. On foggy or misty days, bombers can approach a hostile area at extremely low altitudes, for they are concealed from both air and ground observation and can easily reach their objectives by blind (instrument) flying. On cloudy days, bombers can travel with comparative safety at the cloud ceiling, by taking advantage of the clouds for concealment and emerging from the cloud ceiling only momentarily for orientation on their course or objective. On dark nights, it is extremely difficult for fighting planes to find hostile bombers, even if the weather is clear: especially is this true when the bombers are flying above the range of ground searchlights, which seldom exceeds 15,000 ft. under the most favorable conditions.

Another recent development that materially aids the bombers to elude hostile fighters is the so-called "technique of silent approach," which was first employed during the recent Spanish Civil War. John Langdon-Davies, writing* of the attacks on Barcelona, says that the bombers rose to a great height, shut off their engines many miles out at sea, and glided down toward their objective, so that they could not be detected by listening posts. They then dropped their bombs, undetected by the enemy, and were actually on their way home when the bombs fell on the target. He further states that in 1918 the best gliding angle was about 1 to 20 and that since then great progress has been made, so that now a medium-weight bomber might glide at 120 m.p.h., at an angle of 1 to 30. At this rate a loss in altitude of only 5,000 ft. would permit a plane silently to approach its objective from a point 30 miles away.

* In "Air Raids," George Routledge & Sons, Ltd., London, 1938.

Even if the defensive fighters succeed in locating and closing with hostile bombers, it by no means follows that they will succeed in preventing the bombers from reaching the target area, because of the rugged all-metal construction of modern bombing planes and their heavy armament of machine guns. Against the hostile fighting plane, the bomber of today has little to fear. With multiple machine guns covering all angles of approach, the bomber is now a formidable antagonist for the fighter, even when flying alone and attacked by several fighters at the same time. When flying in normal squadron formation, the bombers are even less vulnerable to the fighters, for the cross fire of machine guns from each bomber tends powerfully to protect the others. Moreover, the modern bomber can sustain an enormous number of hits from machine guns without being put out of action, owing to its rugged construction and the difficulty of hitting its relatively small vital elements. Furthermore, it is now customary to protect each squadron of bombers with one or more squadrons of flanking fighters, whose function is to engage hostile fighters while the bombers proceed on their mission.

If the defensive intercept and pursuit air forces fail to prevent hostile bombers from reaching the target area, the next means of Active Defense is the antiaircraft artillery. Though antiaircraft guns have been greatly improved in range and accuracy since the World War, the difficulty of hitting hostile bombers has also enormously increased, by reason of the greater speed and flying altitude of the bombers, so that the advantage appears still to remain on the side of attacking aircraft. The advantage of the bombers is still further increased by concealment during their approach and the surprise with which they can deliver their attacks. For it is obvious that, no matter how great the efficiency of antiaircraft artillery fire, hostile bombing planes cannot be put out of action unless they are discovered in time for artillery to register upon them, unless they are visible during the time the guns are firing, and unless they are within range of the guns. All the concealment factors that have been mentioned as favoring the bomber as against the fighting plane apply with the same force to the bomber as against antiaircraft fire.

Another form of air attack that is particularly effective against antiaircraft artillery defense is the low-flying (hedgehopping) attack from fast, light bombers or attack planes. These planes may rendezvous at a high altitude, out of sight of their objective, gain very high ground speeds by power diving, and then fly over the objective at extremely low altitudes, seldom exceeding a few hundred feet. They are generally concealed during their approach to the objective by masking terrain features, which are taken advantage of for concealment from view during the approach flight.

Antiaircraft guns are not adapted for firing on fast-moving planes at altitudes below about 3,000 ft.; the only form of antiaircraft fire that can be brought to bear against this form of attack is small rapid-fire cannon (*e.g.*, 37 mm.) and large-caliber machine guns. But even these must be fired point-blank against the attacking planes, for no fire directors can be used under these conditions. For protection against this type of fire, the attacking planes are equipped to lay down blanketing smoke screens, which blind the antiaircraft guns and conceal the planes during their flight over the target area. Although these smoke blankets also cut off the view of the target from the planes, precision methods of bombing are not necessary at these low altitudes and bombs may be dropped with effectiveness by orienting on prominent terrain features visible to the planes above the smoke blanket.

Perhaps the most effective form of defense against low-flying attack planes is the balloon barrage. These were employed to some extent during the latter part of the World War and have since been somewhat increased in altitude and effectiveness. However, they have very marked limitations in the protection of large areas from air attack. To be effective up to the height employed, they must be placed in one or more continuous rings and spaced very close together, *i.e.*, about 100 yd. apart. Hence, to enclose a target area of any considerable size, such as a large city, requires an almost prohibitive number of balloons, with a corresponding number of winches and personnel to man them. But the chief limitation of the balloon barrage is its relatively low effective altitude. During the World War, captive balloon barrages were said to be employed at heights varying from 8,000 to 13,000 ft., although it is doubtful if they were really effective above 10,000 ft. Recent press statements indicate that increased effective heights are now possible, due to improvements in the construction of balloons and mooring cables. However, it is doubtful if any really great increase in effective altitudes has been attained; for the higher the balloon rises, the greater the weight of the cable to be supported by the balloon, and the weight of the cable increases more proportionately to its height. In addition to this difficulty, balloons cannot be let out to their full height even in a moderate wind, and in a high wind they must be hauled down to prevent breakage of the cables and loss of the balloons.

All in all, it is probable that balloon barrages cannot be developed to an effective height of more than 15,000 ft. Although they may thus act as a deterrent to low-flying aircraft, they cannot prevent air attacks that are delivered from high altitudes. Also, if the area to be protected is very extensive and is not completely covered by the balloon barrage—an almost prohibitive proposition—there is nothing to prevent attacking planes from hurdling the balloon barrage and descending within it to any bombing altitude they wish.

Although Active Air Defense can seriously oppose and materially reduce the effectiveness of hostile air attacks, it cannot positively prevent them. As General Groves* so trenchantly points out, "Local (active) air defense can only, in favorable circumstances, afford partial protection against aerial bombardment and then only if it is proportional to the scale of the attack." The present war in Europe has afforded ample demonstrations of this fact. In the light of the recent large-scale air attacks on London, it is appropriate to quote a remarkably prophetic view of the trend of modern war that appeared in the London *Times* of Aug. 18, 1928:

> War has now ceased to be the sole concern of the sailor and the soldier. The advent of the air weapon has made the civilian the real mark. The power to maintain an offensive rests today not with the infantry in the field or the gunner in the ship, but with the civil population who support a nation's complex financial circulation, operate the intricate distributive system which feeds the soldier and the sailor, and man the factories which supply him with munitions. Immobilize that machinery by harrying the men, women and children of a nation into a state of nerves and the will to war may easily disappear, leaving possibly an undefeated army in the field and an unbeaten navy cruising the high sea. Air strategy must take into account the worst that science and chemistry can do in the hands of an unscrupulous enemy fighting with his back to the wall and determined to take any measures to win.

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* GROVES, GENERAL P. R. C., "Behind the Smoke Screen," Faber & Faber, Ltd., London, 1934.

From what has been said above, it is clear that the ability of a country successfully to withstand modern air attack may, in the last analysis, depend upon a well-organized and determined Passive Defense.

Passive Air Defense.—The threefold purpose of Passive Defense is: (1) to prevent casualties among the civil population from air attack; (2) to maintain public morale and to ensure the uninterrupted and orderly progress of industry, especially the manufacture of munitions; (3) in general, to limit to the maximum possible extent damage to property from air bombardment and thus to prevent dislocation of the war effort of the nation.

To attain these objectives, it is necessary to organize and train the public generally as to the powers and limitations of air attack and the means and methods of protection against the consequences of such attacks and to organize each community so that effective steps may be taken to protect life and property and to provide the necessary means to these ends.

The first step in organizing for Passive Defense is to define the respective responsibilities of the national, state, and local governments, so that each will perform its part in the general scheme of defense. Under our form of government, the Federal authority is responsible for the defense of the nation as a whole, and local, state, and municipal authorities are responsible for furnishing protection on life and property within their respective boundaries. This obligation is not suspended in time of war but is rather increased by a state of war, and one of its most serious aspects is the protection of the civil population against air attack, especially in the large urban communities.

The role of the Federal Government in Passive Defense is, therefore, primarily one of supervision and coordination, establishment of fundamental principles and policies of protection, and directing of civilian effort by assisting public and private agencies to carry out their responsibilities in this matter. The function of the state governments is to see that steps are taken to organize an effective scheme of Passive Defense within its boundaries, in accordance with the broad principles and policies laid down by the Federal Government, and to ensure that each local community in the state does its part in the state scheme of defense. The mayor of each incorporated city and town, in turn, is responsible for the organization of his community, in accordance with the general state scheme of defense, and for seeing that all practicable steps are taken to provide his community with the necessary means and measures of protection.

The great bulk of the actual work required in connection with Passive Defense thus devolves upon the local authorities in each urban community, for it is in such communities that the problem of protecting the civil population from the consequences of air attack reaches its greatest scope and application.

The measures required for organizing an urban community for Passive Defense may be stated roughly in the order of priority, as follows:

1. Appointment of a Director of Civil Air Defense with assistants to formulate the general plan for Passive Defense and to supervise the organization and operation of the scheme of defense in accordance with such plan. In organizing the Directorate of Civil Air Defense, existing public and private agencies and utilities should be utilized to the maximum extent.

2. Providing an organization for the instruction of the public as to the powers and limitations of air attack and what measures are to be taken to counter the effects of such attacks. The object of this instruction is to ensure that each citizen knows what to expect in case of air bombardment and what he should do in such emergency, both in his official or business capacity and also as a private citizen.

3. Providing an organization of key personnel required to operate the scheme of Passive Defense, and training them in their specialized duties. This will require the organization of control centers for operating the various instrumentalities of Passive Defense and of schools of instruction for Air Raid Wardens, special auxiliary police, firemen, health department personnel, and such additional municipal services, *e.g.*, crews for the clearance of debris and regulation of traffic, etc., as are required to function during air bombardments.

4. Formulating a complete plan for the evacuation of women, children, and others nonessential in the war effort from the city to outlying rural districts. This involves not only the designation of those to be evacuated and the transportation arrangements to accomplish the movement in an orderly and expeditious manner, but also provision of reception centers in the country for the accommodation of the evacuees and necessary arrangements for food, shelter, and sanitary facilities therein.

5. Establishing a system of air raid alarms to warn the community of the approach of hostile aircraft whenever it is apparent that an air attack is imminent. The alarm system should function in conjunction with the Aircraft Warning System which will be organized and operated by the army. The division of responsibility between the army and local civil authorities in the dissemination of air raid warnings is as follows:

The Aircraft Warning System, operated by the army, will establish a network of observers over all sections of the country liable to air attack and will transmit air raid warning messages to a designated authority in each local community; it will then be the responsibility of each local authority to disseminate alarms within the boundaries of his community.

6. Organizing and training a corps of Air Raid Wardens whose duty it is to guide and advise the citizens and see that all local ordinances affecting the public are carried out during an air attack. The air raid warden system is one of the principal means of ensuring that the general scheme of Passive Defense operates effectively in an emergency and that hysteria and panic are prevented.

7. Providing means for controlling public and private lights, for establishing blackouts, and for operating traffic during blackouts.

8. Establishing a system of public air raid shelters and advising and supervising the construction of private shelters for industrial establishments, hotels, apartments, and private dwellings.

9. Providing means for the protection of public buildings and utilities and public service activities, such as water and power supply, gas and electric services, telephone and telegraph communications, and sewers and drainage, to the end that these instrumentalities may be kept in maximum operating condition despite damage from air bombardment.

10. Providing instruction and means for individual and collective fire fighting. This involves increasing the regular municipal fire department to enable it to cope with widespread fires caused by incendiary bombs, and furnishing advice to public service and private property owners as to appropriate measures to protect buildings and personnel from danger of incendiary bombs.

11. Organizing first aid and medical service for air raid casualties, and providing increased hospital facilities for same.

12. Providing means for protecting individual citizens from gas, including public instructions in the nature of chemical attack and

defensive measures against such attack. This involves: (*a*) provision of means for identification of war gases; (*b*) furnishing gas masks and protective clothing to active workers in Passive Defense organizations; (*c*) supervision of the manufacture of gas protective equipment by private industry so that only efficient appliances will be sold to the public; (*d*) the organizing and training of decontaminating squads and gas cleansing centers.

13. Providing trained personnel for: (*a*) the repair of air raid damage to public buildings and streets; (*b*) the clearance of debris in the streets; (*c*) the rescue of persons caught in damaged buildings; and (*d*) the repair of ruptured gas and water mains, electric power cables, and other public utilities.

14. Establishing an adequate communication system with alternate means of communication which can be brought into play whenever the normal means of communication are interrupted by air bombardment.

15. Formulating schemes for protection of private residences and educating the public as to duties and responsibilities of individual householders.

Since air attacks can be delivered with great suddenness and it is impossible to improvise at short notice all the means required for the necessary precautionary measures mentioned above, it is obvious that Passive Defense plans must be prepared in time of peace for every community and establishment.

The preparation of these plans involves a vast amount of effort on the part of responsible authorities which, in turn, demands a considerable period of time for their accomplishment. Before a Passive Defense plan for a community can be drawn up, it is necessary to make a thorough reconnaissance of the area, collect statistics of personnel to be protected and their normal seasonal and daily distribution, and obtain complete reports on the cover available and protection afforded by existing buildings and utilities. No preparation can be regarded as complete until all individuals have been trained, personnel for Passive Defense duties have been appointed and instructed, and the materials necessary to implement the plan are immediately available.

In view of the foregoing, it is essential that Passive Defense plans should be formulated and put into effect in time of peace, embracing all measures that cannot be completed within a period of a few hours after the declaration of an emergency by the Government.

CHAPTER IV

PROTECTION AGAINST HIGH EXPLOSIVE BOMBS

Most Probable Form of Attack.—In Chap. II, we saw that the most effective weapon for causing major damage to specific targets, especially buildings and utilities of massive and more or less fireproof construction, is the high explosive bomb. Since most military objectives are of this general nature, it is reasonable to assume that these bombs will be the weapon most frequently employed in air attacks against such objectives.

Of the three types of high explosive bomb, the *fragmentation* type is the least serious, from the viewpoint of ease of protection. Fragmentation bombs are relatively small size and low power and are effective only against personnel in the open. Although they may cause widespread and serious casualties among crowds in open places, most ordinary buildings afford adequate protection from such bombs, and therefore no special problem of protection is presented.

We have also seen that heavy *demolition* bombs, though very destructive, are highly localized in their action and can attain their full effect only by a direct hit on a specific target. For this reason, their use is likely to be confined to attack on particularly vital objectives. Since the average bomber can carry only one or two heavy demolition bombs, this type of bomb will generally be reserved for destroying massive targets of great military importance. Hence, the threat of demolition bombs to the civil population in general will be limited to areas immediately surrounding the targets against which such bombs are normally employed.

On the other hand, the thinner cased *general purpose* bomb produces a much more widespread effect and therefore does not require a direct hit on a structure to serve its purpose. This and the fact that a relatively larger number of such bombs can be carried by the average bomber make general purpose high explosive bombs the most probable form of air attack against military objectives, munitions factories, and industrial establishments generally. These bombs, therefore, constitute the most serious threat to the civil population of any type of high explosive bomb.

Method of Protection.—There is but one practicable method of protection against the destructive effects of high explosive bombs, and that is to interpose between the point of explosion of the bomb and the object to be protected a resisting medium having sufficient inherent strength partly to neutralize the destructive power of the bomb. Such resisting mediums are commonly known as "air raid shelters," and the problem of protection against high explosive bombs is, therefore, essentially a problem of the location, design, and construction of such shelters.

Degree of Protection.—The protection afforded by a shelter is not absolute but is one of degree, depending principally upon the size and nature of the bombs involved and the distance through which they fall after release from the airplane. Complete protection is afforded only by a shelter that is capable of withstanding the largest sized bomb in use, when dropped from an altitude affording maximum striking velocity. Only such a shelter is truly "bomb-proof," but it is seldom justified in actual use, because of the great expense involved in its construction. Table II (page 44), which shows the depths of penetration and radii of rupture of high explosive bombs, gives an indication of the large amount of overhead cover required to counter the disruptive effects of these bombs. This matter will be further elaborated later in this chapter.

Objective of Protection.—In dealing with the problem of protection against high explosive bombs, it must be accepted at the outset that universal provision of complete immunity from this danger is impossible of practical attainment. The objective to be sought is, therefore, a balanced program of reasonable protection, considering that in war the factor of time is of vital importance and that it is necessary to avoid an excessive diversion of the national effort from other activities essential to the prosecution of the war. In principle, the protection to be furnished any particular community or establishment should bear relation to (1) its liability to air attack; (2) its vulnerability to such attack; and (3) its value to the nation's industrial economy, in general, and war effort, in particular.

Protection of Essential Activities.—In time of war, the first consideration is the necessity for safeguarding vital industries and other activities essential to the successful conduct of the war. This includes not only the munitions industry, but also vital public services as water, power, light, transport, communications, and the production of food and other necessities of life. In short, production must be maintained and the economic life of the country preserved, despite the utmost destruction that can be wrought by hostile air attack.

Maintenance of Morale.—A second and hardly less important consideration to a country at war is the maintenance of public morale. The chief influence injurious to such morale is the effect of heavy casualties among the civil population. It is, of course, obvious that if the country is attacked by air a certain percentage of civilian casualties cannot be avoided. This fact will be accepted calmly by the public if the percentage of casualties is not excessive, for then the people will have a feeling that the passive measures of civil defense adopted by their Government are sufficient to cope with the problem of air attack. On the other hand, when civilian casualties exceed a reasonable percentage, they are apt to cause widespread demoralization and impairment of industrial effort; this is particularly true where the public gets the impression that the Government's measures of protection against air attack are inadequate and the authorities are unable to meet the situation. Therefore, in formulating a national air raid shelter program, it is of first importance to make sure that the measures adopted for each locality are adequate to afford a reasonable degree of protection to the civil population, the liability of the locality to air attack being borne in mind, as well as its vulnerability to such attack and its relative value to the national war effort. It is also important that the measures of protection adopted for one area be fully extended to all other areas similarly situated.

Evacuation.—Before considering the various means of protection against high explosive bombs, it should be pointed out that no scheme of protection can provide complete immunity to any locality subject to such attack. Hence, protective means should not be substituted for evacuation of the threatened areas, except for such essential personnel as must remain in the area during air attacks. It is generally far better completely to remove from vital and vulnerable localities nonessential civilians, such as women and children, the aged and infirm, and, in general, all those not having specific duties or good reason to remain in such localities. Although the evacuation policy is not strictly a part of the air raid shelter policy, the former does to a considerable extent condition *the latter, since evacuated persons will not require shelter accommodations in the locality from which they have been removed or, to the same extent, in the area to which they are evacuated.*

It is also equally important to clear civilians from certain critical areas surrounding particular targets liable to heavy air attack. In general, no resident should be allowed to remain within a radius of 500 yd. of such targets as munition plants, blast furnaces, or steel mills. For powder plants and factories engaged in the manufacturing of explosives and other inherently dangerous operations, the cleared area should be extended to a radius of at least 1,000 yd. (see Chap. XVIII).

Length of Warning.—An important factor entering into the question of air raid shelters is the length of warning that can be given the civil population in case of air attack. From the viewpoint of convenience of the population in general, the longer the period of warning the better. However, it must be borne in mind that modern bombers, flying at 300 m.p.h., travel 5 miles in 1 min.; for each extra minute of approach toward a target, an additional 5 miles of territory is covered. Hence, the longer the warning period adopted, the larger the area involved in the warning and the greater the immobilization of productive effort. In order to reduce to a minimum interference with production and dislocation of normal life of the country, it is desirable to localize air raid warnings to the maximum degree possible. This involves a reliable prediction of the particular areas over which it is reasonably certain the raiders will successively pass and a minimum length of time between the warning signal and the arrival of the hostile bombers. Another consideration that should not be overlooked in fixing the warning period is the disturbing effect upon the population of a few enemy planes penetrating just far enough to cause a warning signal to be given. The longer the warning period, the greater the number of such warnings and the greater the likelihood of false alarms. False alarms not only needlessly disrupt the life of the community but tend to make the people indifferent to the warning signals and thus neglectful of precautions. After a careful consideration of all the factors, it appears that the warning period of 7 min., adopted as standard in England, is reasonable. But it must be remembered that localities close to the seacoast may not be able to receive as much as 7 min. warning time, owing to the lack of observation stations in the direction of approach of the hostile aircraft.

Length of Travel to Shelter.—The protection afforded by a shelter depends upon its accessibility, as well as on its strength; for, no matter how strongly a shelter may be built, it can extend its protection only to those who can reach it in an emergency. Hence, closely associated with the length of the warning period is the matter of the distance the people must travel to reach air raid shelters, and the time required to travel this distance. Since the warning period is fixed by other considerations mentioned above, it follows that distances to air raid shelters must be adjusted to the length of the warning period and the rate of travel of the people under the adverse conditions usually encountered, *i.e.*, the obscurity of darkened streets and the crowding of large numbers of persons in the approaches converging on the shelter. In determining the rate of travel of people to air raid shelters, allowance must be made for loss of time in putting on clothing, descending from upper stories of buildings, extinguishing lights and fires in households, walking from home to shelter, and gaining access to the shelter in large crowds. All these factors being taken into consideration, it has been found that the maximum reasonable movement to an air raid shelter by day is about 300 yd. and by night 150 yd. In general, the night distance is the controlling factor in locating public shelters.

Maximum Capacity of Public Shelters.—Even in the most densely populated centers, the population seldom exceeds 100,000 per square mile. American cities are generally laid out on rectilinear systems of streets, with an average of 12 city blocks to the mile. The average city block is thus about 150 yd. in length. If the maximum distance of travel of people seeking shelter at night is taken as 150 yd., this means that a public shelter should be located at each street intersection, in order that no one would have to travel more than one block (150 yd.) to reach a shelter. At the rate of 12 blocks per mile, 1 square mile of city area would contain 144 blocks, and, at the rate of 100,000 people per square mile, a city block would average about 700 persons. If shelters are properly located, they would thus average about a 700-person capacity. In the business districts of large cities, it is probable that the floating population during the daytime would increase this average to approximately 1,000 persons per shelter. A capacity of 1,000 persons may accordingly be taken as a maximum for public shelters, except in very unusual situations. Shelters exceeding 1,000-person capacity should be authorized only where local conditions clearly make it necessary.

Size of Shelter Entrances.—Next in importance to the proper location and capacity of public shelters is the matter of the size and form of entrance to these shelters. The first consideration in determining the size of entrance is the rate at which crowds can move through restricted entrances. This matter has been extensively studied in connection with subway entrances during times of heavy traffic and the discharge of large crowds from public buildings, such as football stadiums. The results of these studies indicate that the optimum widths of entrances and exits lie between 5 and 20 ft. and that a safe rate of movement is about 20 to 25 persons per minute through each foot of width of entrance. Shelters of 1,000-person maximum capacity should accordingly be provided with at least two 10-ft. entrances, and preferably with four 5-ft. entrances, in order to enable a maximum of 500 persons to enter the shelter in 1 min. This is based upon a warning period of 7 min., of which the last 4 min. are regarded as the period of movement through the streets; it is assumed that, in crowd movements, half the people will arrive at the shelter during the final minute. In small shelters, an entrance should not be less than 5 ft. wide; for the largest shelters, entrances should not exceed 20 ft. in width and should be divided by guardrails into four 5-ft. lanes of approach.

Wherever possible, entrances to public air raid shelters should take the form of ramps, rather than stairs. Not only are ramps better adapted to the movement of crowds in confined spaces, but they also better facilitate the removal of casualties, should the need arise. The slope of ramps should not exceed a gradient of 1 to 8, and that of stairs 2 to 3, where stairs must be used on account of lack of space. Entrances to public shelters should be provided with gates which can be closed when the maximum number of persons that the shelter is designed to accommodate have entered, unless sufficient guards are stationed at the entrances to prevent undue crowding. Otherwise, there is grave danger that, in stampedes to enter shelters, serious overcrowding will result in crushing people to death and rendering the shelter dangerous to life from foul air. Shelter entrances should also either turn at one or more sharp angles or be baffled, so as to prevent a bomb bursting near the entrance from killing everyone within the entrance passageway.

Classes of Persons to Be Sheltered.—With regard to the problem of providing air raid shelters, the people of a city may be divided into three general classes, in accordance with the circumstances under which they may require shelter, *viz.*, those in the streets, those at work, and those at home. In general, large public shelters are required to accommodate people caught in the street during an air raid; medium sized communal shelters will generally be required for persons at work; and small private shelters will usually suffice for those at home, except for persons who live in large apartments or hotels, for which communal shelters are more appropriate. Since an air raid may occur at any time of day or night, the same persons may require shelter while in the street, when at work, and at home, all in a single day. For this reason and because of the fact that in all large cities there is a daily movement of a considerable portion of the population from the residential to the business area and return, the total shelter accommodations in any city will generally exceed its total resident population, as given by the census. This is particularly true with reference to the business area of a large city. Thus, it is stated that although only 11,000 people sleep in the central part of London, known as the "City of London," over 500,000 work in that area; at any given time during the day, additional scores of thousands may be present in the streets.

In addition to the general population, who may suspend their ordinary activities and seek shelter during an air raid, there is also to be considered those who are engaged in certain important public or quasi-public duties that must be carried on, regardless of conditions, and who must remain at their posts of duty during air raids. Among the most important of these essential workers are (1) those actively engaged in Passive Defense duties, such as Air Raid Wardens, first aid parties, and rescue and demolition squads; (2) regular police and fire-fighting forces and those engaged in operating essential public utilities, such as transportation, communication, water, power, gas, and lighting; and (3) physicians, surgeons, and hospital and sanitary personnel. Since all these persons must carry on at their posts of duty regardless of danger.

special provisions for their shelter and protection should be provided. The same may be said of vital installations, such as munitions factories, essential industrial establishments, waterworks, powerhouses, and hospitals. Each of these installations requires special treatment in the matter of air raid protection.

Policy on Protection.—Since it is usually impracticable to provide effective protection against *direct hits* of the larger sized bombs, it is necessary to formulate a general policy as to the degree of protection that will normally be furnished to personnel and vital establishments. The following policy of the British Government* is cited as a reasonable solution of this complex problem:

I. *Protection of Personnel.*

A. General. In general, protection should be provided:

1. Against blast and fragments from a 500-lb. bomb bursting 50 ft. away.
2. Against falling parts of antiaircraft shell.
3. In special cases, partial protection may be accepted initially (*e.g.*, in the case of buildings, protection up to window-sill level and, in the case of trenches, the omission of overhead cover) (see Appendix).

B. Dispersion. The casualty-producing possibilities of a direct hit must be limited by dispersion. Protection should be afforded on the principle that 50 persons at the most can be affected by a single bomb. This number should be reduced if possible.

C. Limiting Penetration. Though protective measures against direct hits can rarely be provided, it may be possible in special cases to prevent penetration by the smaller bombs or at least to limit their effect. This will usually apply only to buildings that are already provided with overhead cover of considerable strength or to multistory buildings in which the floors are constructed of concrete. Only in the case of buildings of great importance can special construction or strengthening of the existing structure be undertaken for the provision of this class of protection.

D. Passive Defense Workers. When possible, protection against blast and splinters must be provided for personnel on Passive Defense duty, keymen, and others who must remain at their posts during an air raid.

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* "Passive Air Defense," *Pamphlet* No. 3, War Office, London, 1939.

E. Falling Debris. Reconnaissances must be made and demolition parties provided to ensure that an area is safe from falling debris before personnel leave their shelters.

F. Shelters. The form of shelter provided will vary. If the ground is suitable and the necessary labor and material are available, the construction of deep underground tunnels and galleries will provide the best solution and may give protection, even against direct hits of large bombs. Slit or covered trenches will, however, normally be the best form of protection that can be provided, the alternative being the improvement of protection afforded by buildings.

II. *Protection of Vital Establishments.*

A. Buildings and Utilities. In principle, the maximum possible protection against blast and fragments should be given to those buildings and utilities which, if damaged, would seriously interfere with the Passive Defense organization, dislocate the life of the community, or retard the work of important industrial establishments. Such utilities may include telephone exchanges, water and gas mains, sewers, electric power and telephone cables, and vital parts of industrial plants and machinery.

B. Spare Parts. Duplicates of vital parts of industrial plants and machinery should be kept on hand and plans made for the provision of alternative sources of supply of essential services.

C. Isolation of Damage. Damage from air bombardment may be localized and often isolated by posting trained personnel, with a thorough knowledge of all mains, switches, and valves, in the area during an air raid, so that connections to damaged areas may be shut off.

D. Stores and Supplies. The principle of dispersion must be applied to stores and supplies, as well as to personnel, so as to limit loss from air bombardment. The distribution of stores and supplies in buildings will depend upon their liability to damage in fire, water, and gas and upon the possibility of replacement. Inflammable material should be stored where the risk of fire spreading is the least.

It is probable that there will be no time to redistribute stores on the outbreak of war. The normal peacetime system of storage of essential war supplies should be designed accordingly with the requirements of Passive Defense always in view. In cases, however, in which some redistribution on the outbreak of war is essential, the necessary buildings or ground should be earmarked in peacetime, and a complete scheme for effecting the redistribution at short notice should be drawn up.

Classes of Shelter.—Air raid shelters may be classified according to (1) purpose, (2) location with reference to buildings, (3) location with reference to ground level, (4) arrangement, and (5) construction.

1. With reference to *purpose*, shelters are generally divided into three classes: (*a*) public shelters, (*b*) industrial and communal shelters, and (*c*) private shelters. Public shelters are for the purpose of affording protection to people caught in the streets and public places; industrial shelters are for the protection of workers in industrial establishments; communal shelters are provided for persons who reside in large hotels, apartments, and tenements; and private shelters are for those who live in separate homes.

2. As regards *location with reference to buildings*, shelters are of two general classes: (*a*) indoor shelters, in or under buildings; and (*b*) outdoor shelters, detached, and at a safe distance from adjacent buildings, so as not to be involved if such buildings collapse from bomb damage.

3. As regards *location with reference to ground level*, shelters may be divided into three classes: (*a*) *surface shelters*, those built upon and extending wholly above the surface of the ground; (*b*) *semisurface shelters*, those having their foundations below the ground level but extending partly above the surface of the ground; and (*c*) *subterred shelters*, those wholly below the surface of the ground. Subterred shelters are also usually subdivided, in accordance with depth of subterment, into (1) *shallow* dugouts, and (2) *deep* dugouts.

4. With reference to *arrangement*, shelters may be classed as: (*a*) focal, where the shelter accommodations are concentrated in a relatively small area; and (*b*) ramified, where the shelter may extend over a considerable area.

5. With reference to *construction*, shelters may be classified by type of structure, as indicated below.

Protection of Personnel.—The protection of personnel against the effects of high explosive bombs may be accomplished by the use of the following *types of shelter*, roughly in the order of their protective value:

1. Deep tunnels and galleries, where the overhead cover is sufficient to resist the combined effects of penetration and explosion of heavy demolition bombs.
2. Subways and other commercial tunnels.
3. Deep dugout shelters.
4. Cellars, vaults, and strong rooms.
5. Outdoor shelters (other than tunnels).
6. Trenches and shallow dugouts.
7. Conical towers of reinforced concrete.
8. Indoor shelters.
9. Multistory framed buildings.
10. Refuge rooms in ordinary houses.
11. Domestic surface shelters.
12. Outdoor barricades.

Each of the foregoing types of shelter will be briefly considered in this chapter, chiefly with regard to the degree of protection afforded and relative cost involved. A further discussion of air raid shelters for industrial establishments is contained in Chap. XVI, and detailed consideration is given to the protection of private residences in Chap. XVII.

Deep Tunnels and Galleries.—War experience in Europe during the past 5 years has rather conclusively shown that the most effective means of securing complete protection of personnel against high explosive bombs are deep tunnels and galleries, where the overhead cover is greater than the maximum radius of rupture of heavy demolition bombs in the covering medium.

In Table II (page 44), it will be noted that for natural earth the radius of rupture of the largest (4,000-lb.) demolition bomb is 86.7 ft., so that a timbered gallery or tunnel must be at a depth of approximately 90 ft. in order to afford complete protection against the heaviest demolition bomb. If the tunnel is of substantial concrete construction, the safe depth is reduced to approximately 60 ft. If the gallery or tunnel is bored through hard rock or if the overhead cover is of reinforced concrete, the safe depth is reduced to approximately half of that required in natural earth, or about 45 ft., for the 4,000-lb. demolition bomb. The majority of other natural mediums, such as soft rock, chalk, and clay, transmit the rupturing force of high explosive to distances intermediate between those of natural earth and rock or reinforced concrete, so that the safe depths of tunnels in such mediums lie between the limits indicated above. However, such mediums as loose gravel, sand, and made ground are less resistant than natural earth to the rupturing force of high explosives; therefore, even greater depths of subterment of tunnels are required for complete safety.

The safe depths of subterment mentioned in the foregoing paragraph are all based upon the requirement of complete protection from the largest sized demolition bomb. Since such bombs are used only against definite targets of great inherent strength, such as heavy concrete and steel structures, this requirement is unreasonably excessive for the protection of personnel in general.

Since the largest high explosive bombs in ordinary use are the 250-kg. (550-lb.) general purpose bomb and the 300-kg. (660-lb.) demolition bomb, a reasonable degree of protection for personnel is afforded by underground tunnels and galleries having sufficient cover to resist the rupturing force of the latter bomb. The instances in which personnel would be injured in such shelters by larger sized demolition bombs are so rare that the additional expense of providing greater overhead cover is seldom justified.

On the basis of affording complete protection to personnel from high explosive bombs, up to and including the 600-lb. demolition bomb, the following minimum depths of subterment are required for timbered or reinforced concrete galleries and tunnels, in various mediums:

Medium	Construction	
	Timber shelter, ft.	Concrete shelter, ft.
Soft sand and made ground	56	37
Gravel	49	33
Natural earth	47	31
Blue clay	44	29
Soft chalk	39	26
Soft rock	31	21
Hard rock and reinforced concrete	24	16

From an inspection of the foregoing figures, it is apparent that most railroad tunnels and mine galleries meet the requirements for overhead cover and therefore afford complete protection from most high explosive bombs in general use.

The cost of constructing underground air raid shelters in the form of tunnels and galleries is largely a labor cost for excavation and varies considerably with the nature of the ground. If the tunnels are bored in resisting mediums, such as hard chalk and rock, it is not essential to provide any artificial lining. In average mediums, where linings are necessary, the higher cost of brick or concrete over timber or sheet steel is partly compensated by the reduced overhead cover required; *e.g.*, a concrete shelter requires about two-thirds of the depth necessary for a shelter of timber construction.

In addition to the cost of excavating and lining the tunnel and building the ramps, approaches, and exits therefor, the remaining principal item of expense of constructing this type of shelter in average soil is the matter of ventilation and adequate fresh-air supply for the number of persons occupying the shelter. Including chemical filters to purify the air from toxic gas and smoke and the necessary ducts and electric power, the cost of ventilation adds about 20 per cent to the cost of building the shelter.

Regarding the cost of constructing deep tunnel air raid shelters in London, where the soil consists of ordinary earth and clay, Dr. Haldane* quotes a report of a London committee of engineers which estimated the cost of a system of tunnels 50 ft. below the surface of the ground, lined with sheet steel, at £11 per capita of persons accommodated. This estimate included ventilation, air purification, electric lighting, seating, closets, and other extras. At the present rate of exchange (£ = $4), this would amount to about $44 per head. It is probable that this cost would be exceeded in the United States on account of the higher cost of labor here, although for large-scale projects, where highly efficient American laborsaving machinery could be employed to advantage, the increased per capita cost of labor might be largely offset.

The foregoing estimated cost of shelter construction is based upon a tunnel 7 ft. square, with benches at the sides, which will accommodate 4 average persons per linear yard. On this basis, Dr. Haldane estimates that the population of greater London (8,000,000 people) could be completely sheltered in 1,100 miles of tunnels, at a total cost of £100,000,000 (about $400,000,000).

Of course, where unusual soil conditions, such as rock or waterlogged earth, are encountered and it is necessary to drill and blast or work with compressed air and shield, the cost of excavation and tunnel construction increases tremendously. In such cases, the cost of the deep tunnel type of air raid shelter becomes prohibitive, and other forms of shelter must be substituted.

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* In "A.R.P.," p. 168, Victor Gollancz, Ltd., London, 1938.

For normal soil conditions, the cost of deep tunnels is comparable with other forms of shelter affording equal protection. From recent war experience in Europe, it appears that deep tunnels are the most effective form of shelter for the civil population, and many European authorities advocate their use in preference to all others.

Aside from the cost and time required for deep tunneling operations, the chief drawbacks to deep tunnels for air raid shelters is the possible effect of cold and damp on their occupants, especially women and children. Dampness can, of course, be easily reduced by lining the tunnels with waterproof concrete or brick, but the additional cost of this procedure is considerable. In cold climates, especially in winter, even deep tunnels will require some means of heating if they are to be occupied for any considerable time. This factor is, however, not so serious for deep tunnels as for other forms of shelter outdoors, such as trenches, and can generally be met satisfactorily by the use of small, portable oil stoves.

Subway and Other Commercial Tunnels.—In all large cities, there are numerous tunnels, such as underground railroads, subway transportation systems, and vehicular traffic tunnels, those affording communication between important buildings, and conduits for communication systems. From the viewpoint of value as air raid shelters, the subway systems are the most important. The degree of protection from high explosive bombs afforded by the subways depends largely upon their depth below the surface of the ground and to a less extent upon the type of construction.

As a general rule, most of the older subways are 20 to 30 ft. underground and consist of brick, masonry, and concrete arch tunnels. The newer subways are generally at great depths, often exceeding 60 ft., and consist of metal tubes.

In view of the overhead cover required for protection against even medium sized (660-lb.) bombs (see page 88), it is evident that the shallow type of subway is very definitely not bomb-proof against direct hits in many places. And the subway stations are generally far more vulnerable, for they usually are of a large area covered by a roof only a few feet below ground.

Even with these limitations, subway systems do afford a considerable degree of protection; for the effects of bombs penetrating the overhead cover of a subway tunnel would be considerably localized, and there is little doubt that a person in a subway tunnel is, on the average, safer than one in an ordinary building. This and the fact that the subway systems are readily accessible to the man in the street make the advantages of the use of subways as public raid shelters obvious. On the other hand, there are certain disadvantages to this practice that must not be overlooked. In the first place, subways are essential for the transport of people and material, particularly if streets are blocked by demolished buildings, fires, and gas. If subways were used as air raid shelters, as well as for normal transportation, there would be such congestion that many persons would be crushed to death, and the chances are that the circulation of trains would be greatly slowed down if not altogether stopped. In the outlying parts of the city the subway entrances are several blocks apart, and many portions of the city may be as much as 1 mile from the nearest station. If the subways were relied upon for air raid shelter, many people could not reach the stations before they were caught in the streets by falling bombs.

Moreover, there is always the danger that subways may be suddenly flooded from damaged water mains or rendered dangerous to life by leaking gas mains, which are frequently in close proximity to subway tubes. But perhaps the greatest danger in the use of subways for air raid protection is that they are altogether inadequate to accommodate the crowds that would attempt to use them. This would be particularly true if subways were to be solely relied upon for air raid protection and no regular public shelters were provided for this purpose.

The same general considerations apply to the use of vehicular and other commercial tunnels in large urban communities. They are valuable as auxiliary means of protection in emergencies but should not be relied upon as a principal means of protection to the exclusion of regular public air raid shelters.

Deep Dugout Shelters.—Where soil conditions are favorable, *i.e.*, in the absence of rock and waterlogged earth, it is often more economical to secure overhead protection for an air raid shelter by going deeper into the ground, so that the natural earth forms the requisite overhead cover, in lieu of a specially built roof. This type of shelter is nothing more or less than a deep dugout, or underground cave, which is reached by an inclined tunnel or steps. The depth at which such a shelter is built is largely a matter of choice; the deeper the shelter, the greater the degree of protection obtained.

Since a minimum of 2 ft. of firm natural earth is required to protect against blast and fragments of a 500-lb. bomb bursting 50 ft. away, if the dugout type of shelter has only this minimum overhead cover, it is in effect no more secure than a semisurface outdoor shelter with artificial earth cover of the same thickness. For this reason, the prevailing practice in constructing the dugout type of shelter is to provide at least 8 to 10 ft. of overhead cover which will afford protection against all hazards except direct hits by high explosive bombs of 100 lb. or more. The advantage of sinking dugout shelters to this depth is that in resistant soil, such as chalk or clay, no lining for the shelter is required, whereas, if the minimum overhead cover of 2 ft. only is provided, it will be necessary to line the shelter with wood, sheet steel, or concrete.

As it is not desirable to shelter more than 50 persons in one room, the dugout type of shelter for larger crowds generally take the form of a series of underground chambers, spaced not less than 25 ft., and preferably 30 ft., apart and connected by a communicating gallery. This arrangement is better than a continuous tunnel; for the latter does not provide for any localization of burst, and this is essential if the shelter is only splinter-proof. The communicating gallery should have a minimum width of about 2 ft. 9 in. and height of 6 ft. 6 in., with several entrances not less than 5 ft. in width.

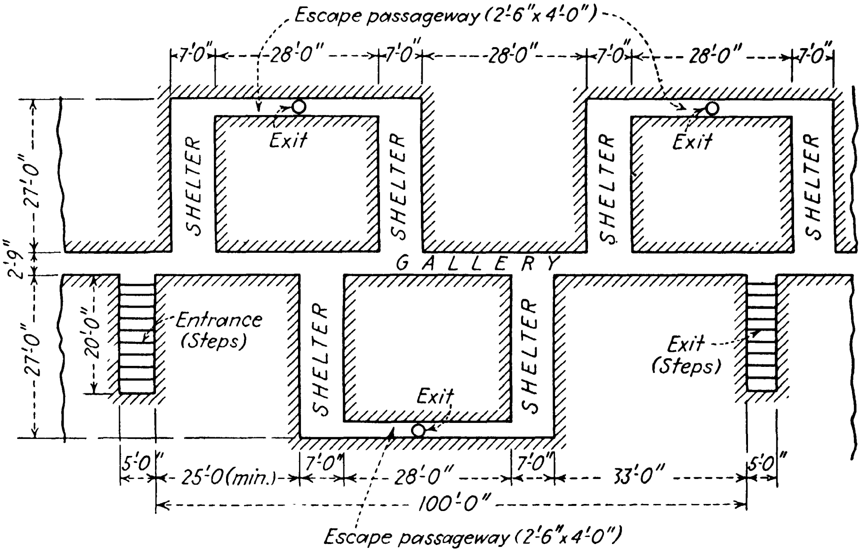
The dugout chambers vary in size according to the number of persons to be accommodated. The limiting factor in determining the occupant capacity of an underground shelter is ventilation. For shelters ventilated naturally by way of the normal exits and entrances but without forced (mechanical) ventilation, the following allowances may be taken as a guide in estimating the maximum number of persons who can be accommodated, on the assumption that the entrances and exits will be habitually kept open between air raids, when no gas is present in the vicinity:

For every person in the shelter, not less than:

6 sq. ft. of floor area of shelter.
50 cu. ft. of capacity of shelter.
25 sq. ft. of surface area (walls, floor, and ceiling).
(Whichever rule gives the least number of persons.)

On this basis, one of the most economical sizes of underground dugout shelter is 27 ft. long by 7 ft. wide by 6 ft. 6 in. high. This shelter will accommodate 25 persons without forced ventilation and 50 persons with forced ventilation and is based on three rows of seating, with an 18-in. seating allowance per individual, including an extra length of 18 in. for a chemical latrine, but no allowance of space for an entrance ramp.

If the shelter is both unventilated and *gas-proof*, the superficial area (walls, floor, and ceiling) allowance per occupant must be increased to 75 sq. ft., the capacity of the above-mentioned shelter being thus reduced to about 10 persons. On this basis, shelters may be occupied for periods up to 6 hr. Here, again, if suitable arrangements are made for drawing fresh (gas-free) air into the shelter, the permissible number of occupants may be increased to a maximum of 50. Where the capacity of a shelter is limited by the factor of ventilation, it must be borne in mind that additional occupants can be accommodated for limited periods without actual danger to life, but with some discomfort due to foul air. The limit of capacity from the standpoint of ventilation will be more fully discussed in Chap. VI.



All shelters and gallery: 6'-6" high

FIG. 15.—Dugout shelters.

Figure 15 shows an economical arrangement for a large underground dugout type of shelter, accommodating several hundred people and meeting the standards of protection mentioned above.

The per capita cost of deep dugout shelters varies considerably with the character of soil and nature of the lining. A cost of about $10 per capita may be taken as a fair average for a dugout shelter of 50-person capacity.

Cellars, Vaults, and Strong Rooms.—Many buildings, especially of the commercial type, such as banks, large stores, and warehouses, have in their sub-basements stoutly built cellars, vaults, and strong rooms which are often two or three floors below the ground level. These rooms are generally of small dimensions and have strongly vaulted ceilings of masonry which would hold fast if the buildings above them were wrecked by bomb blast or shock.

Many of these cellars and subterranean strong rooms extend out under the pavement of the sidewalk and street; and provided that there are a few feet of earth between their roofs and the overlying pavement, they make excellent air raid shelters and will furnish protection even if the buildings to which they pertain are completely demolished. Such shelters are, of course, not proof against direct hits by large high explosive bombs, unless they are so far below the street level as to have the overhead cover required for this purpose (see page 88).

Even where the floor over a basement cellar is incapable of supporting the load of debris that may fall on it when the building is demolished by bomb damage, it can be strengthened by the use of additional columns or girders of steel or concrete for this purpose. This has been done on a very extensive scale in Europe during the last few years, and such shelters have no doubt saved thousands of lives.

The extent to which the floors over basement shelters need strengthening, in order to withstand falling debris, is indicated by the following assumed loads, which are additional to the live and dead loads the floor is normally designed to carry:*

1. For buildings composed of load-bearing masonry or brick walls and having 2 stories above basement, assumed load is 200 lb/sq. ft.; for 3 or 4 stories over basement, 300 lb./sq. ft.; and over 4 stories, 400 lb./sq. ft.

2. For steel or reinforced concrete frame buildings, the debris load may be assumed at 200 lb./sq. ft. of floor area, irrespective of the number of stories above the basement (see Appendix).

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* *Air Raids Precautions Memorandum* No. 10, 1st ed., His Majesty's Stationery Office, London, 1939.

In the case of cellars that lie directly beneath the ground floor of a multistory building, it is essential that the floors above be sufficient in number and strength to ensure that at least a 500-lb. bomb striking the roof of the building will not penetrate to the cellar before exploding. This requires a minimum of six floors of 6-in. concrete slabs or material of equivalent strength. Where these conditions do not exist, it is necessary to subdivide the cellar by stout partition walls, in order to localize the burst of a penetrating bomb.

The chief drawback in the use of cellars, vaults, and strong rooms is that most of them have only one entrance and are generally deficient in ventilation. Even so, it is usually much easier and far less expensive to supply these deficiencies in existing rooms than to build air raid shelters especially for the purpose.

The cost of constructing air raid shelters from cellars, vaults, and strong rooms having the requisite roof strength to withstand falling debris is chiefly the expense of providing an additional exit and ventilation. Even where these roofs need reinforcement to withstand debris loads, the cost of this work is only a fraction of the cost of building a new air raid shelter of the same capacity and strength.

Outdoor Shelters (Other than Tunnels).—In Europe, much time and effort have been devoted during the past 5 years to the design and construction of so-called "bomb-proof" shelters, and there now exists an extensive foreign technical literature on this subject. It is not our purpose at this point to enter into a detailed consideration of shelter design and construction, as these questions will be dealt with *in extenso* in subsequent chapters. We shall, however, here mention certain general aspects of the question of outdoor shelters, as one of the most useful means of protecting personnel from the effects of high explosive bombs.

The term *outdoor shelter* is applied to various forms of protective structures that are built at such distances from existing buildings as to be safe from falling debris, in case of collapse of such buildings from bomb damage. The minimum safe distance from a building should be never less than half the height of the building, and preferably equal to the height of the building. The advantages of shelters so located is, of course, obvious, since one of the greatest dangers to shelters located inside buildings is the collapse of the shelter from the impact of falling walls and other debris. There is also the additional advantage that outdoor shelters, being separated from adjacent buildings by safe distances, are not liable to destruction by fire or envelopment in flames, in case these buildings catch fire. Even a fireproof shelter in a burning building may become untenable to its occupants from surrounding flames and heat, but this is not the case with properly located outdoor shelters.

The principal disadvantages of outdoor shelters, as compared with indoor shelters, are: (1) the additional time and inconvenience of gaining access to the shelter; (2) less protection against the weather and the possible effect of cold and damp. In general, the first item is by far the more serious, and special consideration must be given to so locating the outdoor shelter as to ensure its occupation on short notice at night. As a general rule, every communal and private shelter should be so located that it can be occupied by all personnel it is intended to accommodate within 5 min. warning from their normal places of work or sleep. This rule applies not only to shelters for family dwellings, but also to shelters for the protection of factory workers and residents of large hotels, apartment houses, and tenements.

For reasons that have been previously mentioned, it is impracticable to provide outdoor shelters that are absolutely safe from direct hits by large high explosive bombs. The prevailing practice is, therefore, to build shelters that afford a reasonable protection against the most probable dangers from air bombardment. The British rule is to provide shelters that afford protection against blast and fragments from a 500-lb. bomb bursting 50 ft. away. This rule was adopted after a careful study of bomb damage, based upon experimentation and war experience, and appears to be a rational solution of the problem.

There are many types of outdoor shelter, varying from simple covered trenches to heavy concrete or steel structures, partly or wholly underground. The first consideration in the provision of a shelter is that it shall give overhead and lateral protection of the approved standard. The required standard of *overhead* protection against blast and fragments from a 500-lb. bomb bursting 50 ft. away is afforded by: ¼ in. of mild steel plate; 4 in. of reinforced concrete; 6 in. of ordinary concrete; brickwork or masonry arches of not less than 8½ in. crown thickness; or 18 to 24 in. of earth, sandbags, ballast, or broken stone. If immunity against direct hits of the most frequently used bombs (*i.e.*, up to 550 lb.)

is desired, the overhead cover of the shelter must be increased to a minimum of 7 ft. of reinforced concrete. Since protection on this scale for large numbers of people would involve immense cost, it is considered impracticable for general use, and the first-mentioned standard of overhead cover is the one most widely used. The required standard of *lateral* protection for outdoor shelters is secured by 1½ in. of mild steel plate; 13½-in. walls of good brickwork (*i.e.*, 1½ brick thick) or sound stone masonry; 12 in. of reinforced concrete; or 30 in. of earth, sandbags, ballast, or broken stone (see Appendix).

Other important principles of outdoor shelter construction are as follows:

1. *Dispersion.* Shelters should consist of units accommodating parties of not more than 50 persons each and should be scattered as widely as possible in preference to being placed in one group. The distance between adjacent shelters should never be less than 25 ft. and should be increased to 30 ft. wherever space permits. Where two parties are accommodated in one shelter, all protective walls between parties must extend from one side wall to the other and up to the ceiling.

2. *Entrances and exits.* Each shelter must have at least two entrances or a main entrance and an emergency exit, and these should be as far apart as possible, so that both are not likely to be blocked by bomb damage at the same time.

3. *Ventilation and gas-proofing.* An adequate supply of fresh (gas-free) air must be furnished to each shelter in accordance with the number of occupants, and means must be provided to prevent the entrance of toxic gas into the shelter. Means and methods of gas-proofing will be considered in Chap. VI.

4. *Independent lighting.* As the normal source of electricity may be cut off by bomb damage, each shelter must have alternate means of lighting. In small shelters, oil lamps or even candles may be used for alternate lighting.

5. *Water supply.* A suitable supply of drinking water must be provided. In small shelters, this can be accomplished by storing water in suitable receptacles.

6. *Flooding.* Means should be provided to prevent entrance of water into the shelter from surface drainage or from damaged water mains in the vicinity. This may be done by building parapets around the shelter or by the use of tide boards.

7. *Sanitation arrangements.* Chemical closets may be used for this purpose, if water closets are not available, but suitable provision must be made.

8. *Tools.* Essential tools, such as picks, shovels, and crowbars, should be stored in the shelter to aid in forcing an exit, if occupants are trapped by bomb damage.

The per capita cost of outdoor shelters varies greatly with the size, type of construction, and elaboration of interior facilities and equipment. Even without gas-proof doors and chemical filters, etc., Dr. Haldane* estimates their cost at £20 to £50 per head. Even at the minimum figure, outdoor shelters cannot be built as economically per capita as deep tunnels, except for small groups of persons in isolated locations. The question, therefore, of whether deep tunnels or outdoor shelters should be built in any particular place will depend largely upon the character of the soil, the number of persons to be protected, and the balance of convenience, as to accessibility, between these two forms of shelters.

Trenches and Shallow Dugouts.—Owing to the fact that craters formed by exploding bombs project the blast and fragments upward in a conical sheaf, trenches, even without overhead cover, afford a material degree of protection against the effects of such bombs. When trenches are provided with overhead cover, they are equal in protective value to underground dugouts and galleries with the same depth of overhead cover. Trenches should have a depth at least exceeding the height of a tall man, and a minimum depth of 6 ft. 6 in. from floor to top of parapet is widely accepted as standard in Europe. The width of the trench should not exceed 3 ft. at the bottom, with side walls having a slope of 5 to 1, and revetted by corrugated iron sheets or horizontal wooden planks, held in place by 4- by 2-in. vertical struts (see Fig. 16). Both corrugated iron sheets and wooden planks will rot out in time unless specially treated to resist moisture. Greatly increased durability can be obtained by coating corrugated iron sheets on both sides with bitumen and by impregnating lumber with creosote under pressure. However, concrete is a more economical and durable lining for trenches that are intended to be used for a considerable length of time. The concrete lining may be laid in place by the use of wooden forms, or the lining may be made up of precast units of concrete or sheet metal.

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* *Op. cit.*, p. 178.

In order to localize the effects of an exploding bomb, trenches should be made not straight, but either zigzag or traversed, with not more than 10 yd. between angles or traverses. Lines of trenches should be spaced at least 15 yd. apart (see Fig. 17).

One of the principal considerations in locating trenches is the problem of drainage. Ground that is soft, wet, and liable to flooding should be avoided. Drainage should be secured by sloping the bottom of the trench toward one end and providing a ditch below the floor level of the trench which empties into a sump at the low end of the trench. Pumps or other suitable arrangements must be made for emptying the sumps. Floor boards should be laid on the bottom of the trench over the drainage ditch.

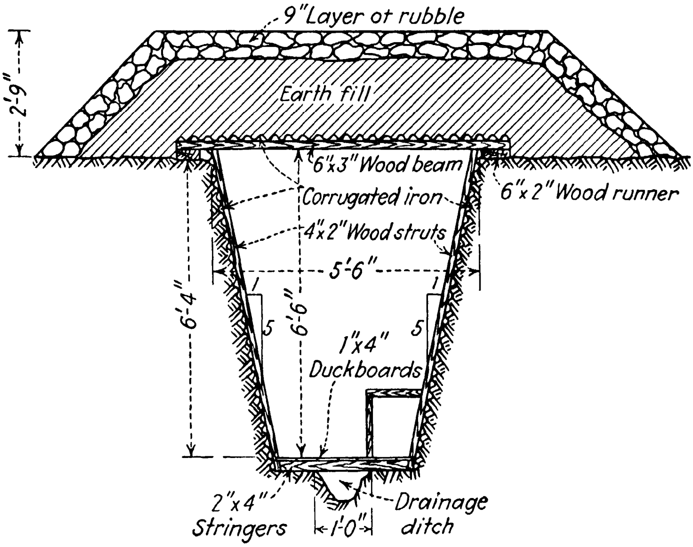

FIG. 16.—Section of covered trench.

For the shelter of small parties, such as families in detached homes, a small semisurface shelter, known as the "Anderson shelter," has been standardized and widely adopted in England. This shelter is constructed of sheet steel arches, which come in prefabricated sections, adapted to be locked together along the top of the arch. They can be had for single-, double-, or treble-row seating and can be employed entirely below ground or partly below and partly above the ground level. When emplaced in a semisurface setup, they are sunk to about half their depth in the ground and then covered with the excavated soil to a minimum depth of 2 ft. over the top of the arch. The semisurface emplacement is particularly adapted to localities where the subsoil water level is so close to the surface of the ground as to preclude the digging of trench shelters. Anderson type shelters also involve the minimum of time and effort to construct and are said to afford adequate protection against blast and fragments of a 500-lb. bomb bursting at a distance of 50 ft.

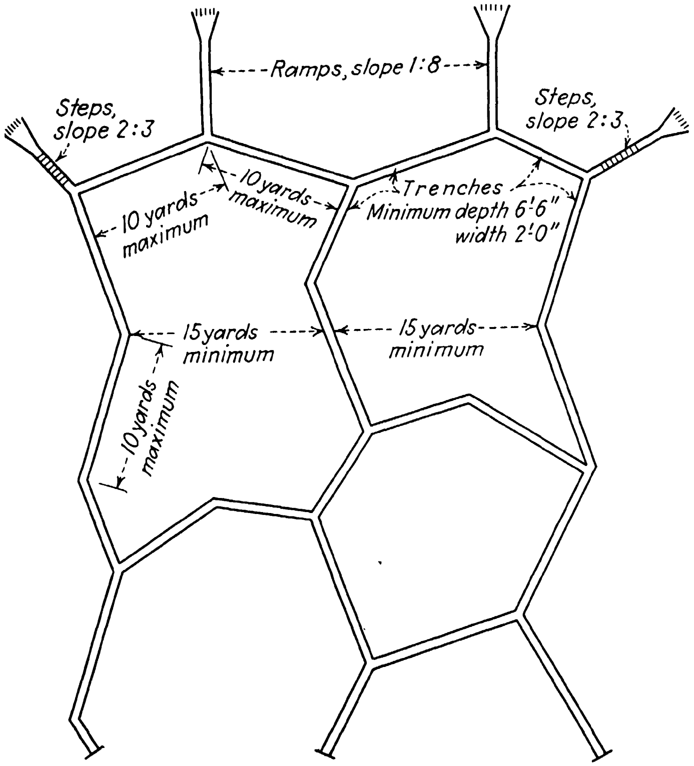

FIG. 17.—Open trench shelters. Siting arrangement.

Conical Towers.—Where shelters are built wholly aboveground, it is necessary to provide them with very strong roofs, in order to afford complete protection against even medium sized high explosive bombs. Thus, it requires 15 ft. of reinforced concrete to resist a direct hit from a 500-lb. general purpose bomb. Since such massive construction is exceedingly expensive, alternate schemes have been proposed for securing adequate protection from high explosive bombs in surface shelters. One of the most promising of these proposals is conical towers of reinforced concrete which have been erected in Germany. Here the idea is that if the roof of a surface shelter is made sufficiently steep a bomb striking it will glance off the side and burst harmlessly in the air. The towers are accordingly built like lighthouses, about 80 ft. high, with circular bases, steep sloping sides, and conical tops, the tops being only slightly smaller than the bases. The walls are made of reinforced concrete 4 to 5 ft. thick, and the interior of the tower is provided with a series of platforms and seats, connected by a spiral staircase. Each tower accommodates approximately 600 people.

It is claimed that these towers are far less expensive, per capita, than other forms of surface shelters and that they afford adequate protection against high explosive bombs. The last-mentioned claim may be open to question when it is remembered that falling bombs often strike at an angle of as much as 40° with the vertical. To this angle must be added the angle of slope of the tower walls. This may increase the angle of impact to something in the neighborhood of 55°, which might easily be sufficient to cause the bomb to burst on contact with the wall and thus wreck the tower. Whether conical towers of the type indicated are effective against high explosive bombs can, of course, be determined only by actual test. If such tests demonstrate their effectiveness, they may prove to be the most economical form of surface shelter.

Indoor Shelters.—In general, indoor shelters are of three types, depending principally upon their location within the building in which they are contained: (1) those constructed *under* the basement or foundation of the building; (2) those constructed *in* the basement or lowest floor of the building; and (3) those constructed *in some other part* of the building, usually by specially reinforcing a room selected for this purpose.

Except where indoor shelters are constructed *under* buildings, at depths approximating those pertaining to outdoor shelters, indoor shelters in general do not afford the same degree of protection as outdoor shelters underground, since it is generally impracticable to provide the same degree of lateral and overhead protection for shelters indoors as for underground shelters outdoors. On the other hand, indoor shelters are usually more accessible and convenient to people in the building and, as a rule, are more comfortable. So the choice between outdoor and indoor shelters, where conditions are such that either may be provided, resolves itself into a balancing of safety against comfort and convenience.

As a rule, however, the choice is not always possible, since frequently lack of available space precludes the construction of outdoor shelters within permissible distances of the building. When other things are equal, outdoor shelters are preferred because of their greater safety.

The guiding principle in locating indoor shelters is to make the best of whatever protection is available wherever it falls short of the minimum standards adopted for this type of shelter. As a rule, shelter below ground is preferable, as it usually affords the best protection against blast and fragments. In stories above the ground level, there is always the danger that fragments from high explosive bombs falling near a building may strike upward through a window below and then through the floor of the shelter. For this reason, where there is no basement in a building, a protected room on the ground floor is usually the best location for an indoor shelter. The next best location for an indoor shelter is an inner room upstairs, but not on the top story. The most favorable is a corridor or inner room without windows or, at least, a room with a window facing a narrow court or alley, so as to secure partial protection from neighboring walls. In general, rooms with small windows are preferable to those with large windows. Whatever room is selected for an air raid shelter, it should be provided with the standard lateral and overhead protection, wherever possible (see page 96). If no available room in the building can be adapted as a suitable shelter, some form of outdoor shelter should be constructed.

In general, buildings of steel frame or reinforced concrete construction are best adapted to house indoor shelters, for such buildings are less liable to complete collapse when struck by a high explosive bomb. The roof or floor immediately above the shelter and the walls supporting the roof or floor must be strong enough to carry the additional loads that may be imposed by falling debris in the event of the collapse of any part of the building above (see page 94). The space selected for the shelter should not be directly under specially heavy floor loads above, such as vaults or heavy machinery.

Though it is better that indoor shelters be located so as to avoid pipes carrying gas, steam, and hot water, on account of the danger to the occupants if damaged, where this cannot be avoided, means should be provided so that the occupants of the shelter can promptly shut off all such services from the shelter area. The same may be said with regard to the possibility of basement shelters being flooded by damaged water mains. Though steps should be taken to prevent this possibility, otherwise suitable underground shelter should not be disregarded solely because of this danger, provided that sufficient exits are arranged so that occupants may leave the shelter in case of flooding.

As with outdoor shelters, shelters in buildings should always be provided with at least two exits, one of which may be used by the occupants of the shelter in the event the other is blocked by falling debris. In principle, the alternate exit should be as far as possible from the main entrance or exit and should lead to the open air at a distance from the building safe from falling walls and debris.

Indoor shelters, like other types, should be designed to accomodate not more than 50 persons in any one room, in order to minimize the casualties likely to result from a direct hit. Where it is necessary to accommodate more than 50 persons in a shelter, the maximum number to a shelter should be limited to 200 and strong dividing walls should be constructed between subdivisions sheltering 50 persons each.

Some form of emergency lighting should be provided in shelters to guard against failure of the normal lighting system. For large shelters a permanent alternate electric lighting system should be installed; but the engines, generators, and batteries should be isolated from the shelter room proper, provided with separate ventilation, and protected as much as possible. In small shelters, flashlights and candles may be used for emergency lighting, the former being preferred because they do not consume the oxygen in the air.

Each shelter should be equipped with sanitary facilities, if possible, within the shelter. Chemical closets are useful for this purpose. One closet seat should be available for each 25 occupants, with subsidiary buckets and urinal facilities. Closet partitions should be the full height of the room.

The rules previously mentioned for outdoor shelters regarding size and capacity of shelters and the ventilation thereof apply to indoor shelters. The design, arrangement, and construction of indoor shelters for industrial establishments and private residences will be further discussed in Chaps. XVI and XVII.

Multistory Frame Buildings.—As a rule, multistory buildings of steel frame or reinforced concrete construction have a greater capacity for resisting bomb damage than buildings of masonry and brick where the floor-loads are carried by the walls. Recent war experience in Europe and the Far East has shown that large steel frame and reinforced concrete buildings do not collapse, even when struck by the heaviest demolition bombs. Thus, a 660-lb. demolition bomb, with delayed action fuse, will usually penetrate the roof and five or six floors of an average steel frame or reinforced concrete building before exploding. When it explodes, it generally smashes the rooms on each side and above and below the point of burst; but the building as a whole still stands, and most of the people in the building escape with their lives.

In general, the greater the number of stories, the safer the building, as a whole, for its occupants; for even the larger demolition bombs will not penetrate more than 8 to 10 stories before explosion, and the resulting severe damage is largely confined to the bays of the building within 50 to 100 ft. of the point of explosion. Dr. Haldane* estimates that a person in a steel frame building stands perhaps one-half or one-third of the chance of being killed as a person in a neighboring brick house. As multistory steel frame and reinforced concrete buildings are the prevailing type of construction in the metropolitan areas of most large American cities, it would seem that they would, on the whole, be far less vulnerable to high explosive bomb attack than European cities, at least in so far as pertains to loss of life among the civilian population.

In general, the safest rooms in a multistory steel frame or reinforced concrete building are, first, those on the lowest floor below the ground level, then those above the fourth or fifth floors, which are generally out of the range of blast and fragments from bombs falling in the street, but not closer to the roof than 8 or 10 floors. As many American buildings are over 20 stories high, the middle stories would probably be very effective natural shelters, without any special treatment.

Refuge Rooms.—The term "refuge room" is generally applied to a room in a private dwelling that has been specially selected and fitted up as an air raid shelter for the occupants of the household.

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* *Op. cit.*, p. 145.

A properly prepared refuge room can give almost as good protection against blast and splinters as a trench or an Anderson type shelter. It has the further advantage that persons using it do not have to go outdoors at night or in cold, wet weather and that it is usually warmer, drier, and more comfortable to live in.

As with other types of shelter, a refuge room below ground is preferable because it gives the best natural protection against blast and splinters. Where underground refuge rooms are not available, very good protection can be obtained aboveground where the refuge room is well enclosed by brick or stone walls. The general considerations mentioned in connection with outdoor shelters in general (page 95) apply to the selection of a room for a refuge; the guiding principle is to choose a room that is already protected as much as possible by surrounding walls of brick, stone, or concrete, including those of the house next door.

Windows and doors of refuge rooms that are not already shielded by another house or solid wall within a distance of 30 ft. must be specially protected against bomb blast and splinters by blocking them up or by erecting barricades around them outside the building. In either case, the protection should be raised to a height of at least 6 ft. above the floor of the room, so that occupants walking about in the refuge room will not be in danger of splinters. The simplest way to block a window or door that is not needed for an exit is to brick it up with good brick masonry, 1½ bricks (13 in.) thick. A less expensive method is to build a frame crate over the outside of the window or door and fill it with earth, loose gravel, or shingle to a thickness of 24 to 30 in.

For windows that cannot be blocked up, even if shielded by outside barricades, it is necessary to protect the glass from flying into fragments when shattered by blast. Apart from the discomfort of broken windows in cold and wet weather, there is danger of injury from flying pieces of glass and also of toxic gas entering the room if present outside. The three most usual methods of reinforcing panes of glass are:

1. Paste a suitable covering, such as tough paper, cardboard, cloth, or cellophane, over the glass.
2. Cover the whole window inside with wire netting.
3. Fit a lightweight screen inside the window.

A good covering, properly applied, cannot prevent a glass pane from breaking when a bomb explodes near by, but it can prevent glass flying about in dangerous pieces and leaving holes in the pane for the entrance of weather and gas. Finally, the floor or roof above a refuge room should be braced and strengthened so as to bear any load of debris that is likely to fall on it if the roof or walls of the building collapse from bomb blast.

The various methods of preparing a refuge room are described in Chap. XVII on Protection of the Home.

Domestic Surface Shelters.—These shelters are of the outdoor type, usually built in the back yard of a private dwelling, for the purpose of sheltering the occupants of the household during air raids. Domestic surface shelters are placed within a distance of 6 to 15 ft. from the house, for convenience of entry and in order that the walls of the house may serve as a protection for the entrance to the shelter. If the shelter is located a greater distance than 15 ft. from the house, in order to avoid falling debris, the entrances should be screened by a brick or concrete wall to protect them against blast and fragments.

Domestic surface shelters are generally constructed of brick, concrete, or block masonry and are used in lieu of semisurface and underground types of shelter, where soil conditions prevent digging in, *i.e.*, on waterlogged soil or paved yards. The standard floor dimensions of a single unit shelter for 6 persons is 6 ft. 6 in. long by 4 ft. 6 in. wide. An additional 2 ft. of length is added for each 2 persons in excess of 6.

The shelters may be built either as single units or as multiple units, grouped in various ways. Where houses are semidetached or in rows, domestic surface shelters are usually constructed as a double-unit shelter, with an entrance on each side of the fence between adjoining back yards. Where two rows of houses are built back to back, with adjoining back yards in between, domestic surface shelters are most economically constructed in groups of four-unit shelters each (see Fig. 18).

The work of construction follows normal masonry practice, and no special precautions are required. Where the shelter is to be built on an existing pavement, no floor is required; but if built on soil, the turf should be removed and the underlying soil well consolidated before the floor is laid. The external walls of the shelter should be 13½-in. standard brickwork or 15 in. of sound concrete; the internal walls, of 4½-in. brickwork or 4 in. of concrete. The roof should be built of 5 in. of reinforced concrete.

The cost of domestic surface shelters is considerably more than that of the semisurface and dugout types of domestic shelter of the same capacity and degree of protection; and although they are generally drier and more comfortable, their increased cost is seldom warranted where soil conditions permit the building of semisurface or dugout types.

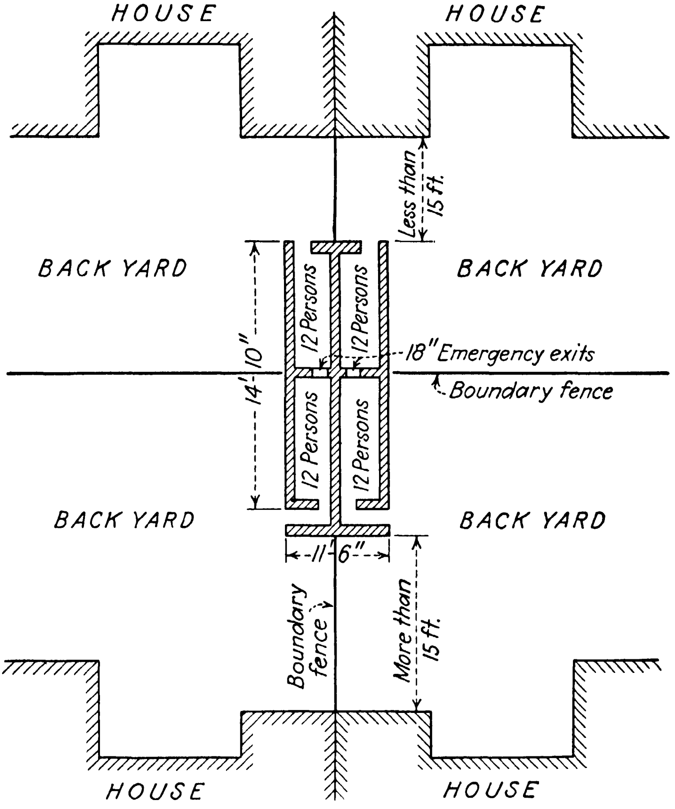


FIG. 18.—Domestic surface shelter, quadruple type.

Outdoor Barricades.—For those who work outdoors and must remain at their posts of duty during air raids, regardless of danger, the only practicable protection from blast and fragments are various kinds of barricades. Barricades are usually built in the form of a circular wall around the spot or object to be protected and are carried up to a height at least equal to a man's shoulders. Where it is not necessary for the occupants to have a clear view of the field around the barricade, this is extended to a height of 6 ft.

6 in., in order better to protect the occupants against flying fragments. The entrance to the barricade may be formed by laying the wall in the form of a spiral, with about 60 to 90° overlap.

One of the most satisfactory kinds of barricade in view of its relatively low cost, rapidity of construction without the use of skilled labor, availability of materials, and high protective value is made of sandbags. An ordinary sandbag of the Army pattern is about 33 in. long by 14 in. wide when empty. When filled about three-quarters with sand or earth, a bag measures approximately 20 by 10 by 5 in. and holds a little over ½ cu. ft. of filling.

When a sandbag is laid with its longer side parallel to the face of the wall, it is called a "stretcher"; when laid at right angles to the face of the wall, it is a "header." The wall is erected by laying the sandbags in alternate header and stretcher courses, the first course being headers. In laying the wall, headers are placed with their tied ends inside, and stretchers with the seam of the bag inside, care being taken to break vertical joints. The wall is generally vertical on its inside face and slopes back on its outer face with a gradient 4 to 1.

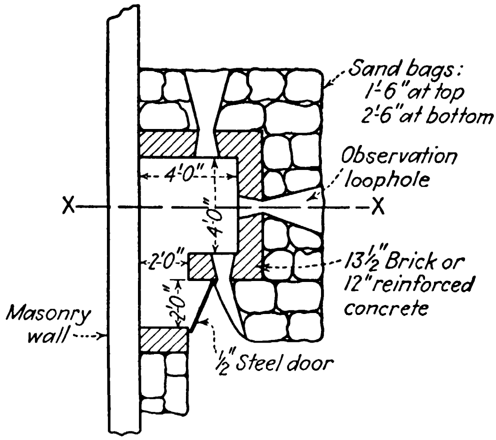
For a barricade 6 ft. 3 in. high, 15 courses are required, the bottom course being 3 ft. 6 in. thick and the top course 2 ft. thick. This gives the wall an average thickness of 2 ft. 8 in., which is sufficient for standard protection against blast and fragments. Five men, three filling and two laying, can place 60 sandbags an hour, if not above shoulder height.

For open barricades, an average floor space of approximately 5 sq. ft. per man is allowed, so that a circular barricade 4 ft. 6 in. in diameter would accommodate three men.

Where a solid brick or masonry wall, at least 13½ in. thick is available, it may be utilized as one side of the barricade by abutting the ends of the barricade against the wall. In this way, fewer sandbags are required for the same number of occupants. Thus, a semicircular barricade of 3-ft. radius will accommodate three men (see Fig. 19).

Outdoor barricades may also be built by earth or sand-filled revetments which may consist of a large variety of revetting materials, such as (1) wooden pale fencing, held together by wire ties; (2) iron railings and wire netting; (3) wooden posts and corrugated iron sheeting; and earth-filled wooden boxes, piled in courses, and held together by wire ties and netting. In all these forms of barricade, the minimum thickness of earth or sand should be 2 ft. 6 in.

Selection of Shelters.—From what has been said above concerning air raid shelters, it is apparent that, although there is a wide variety of choice among the different types of shelters, it is, as a general rule, impracticable to provide *absolute* protection for the large majority of the population of a big city. Before embarking upon a shelter program for any community, a definite policy should be formulated, setting forth: (1) what classes of people are to be protected, where and for what periods of time: (2) the degree of protection to be afforded the various classes; (3) the standards of protection to be adopted; and (4), in general, the types of shelter to be made available to various classes.



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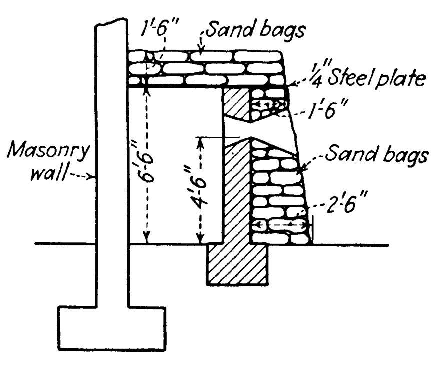

ELEVATION-SECTION X-X

Fig. 19.—Sandbag barricade against masonry wall.

Having formulated a definite shelter policy, the next step is to conduct a thorough reconnaissance of the community, with a view to determining the need for various types of shelter and the extent to which existing buildings and structures may be made available to meet those needs. Existing buildings should be carefully examined as to their suitability for air raid protection and the facility with which they can be improved to meet required standards of protection.

In principle, the normal use of buildings should be disturbed as little as possible, and, wherever practicable, existing buildings should be adapted; special construction should be undertaken only in cases where adaptation is impossible. In general, evacuation is preferable to shelter protection, but special consideration must be given to those keymen who must remain at their posts and carry on their duties during air raids, regardless of danger.

With regard to the selection of shelters for a particular purpose, there can be no hard and fast rule, and each case must be considered on its merits.

Preparation of Shelters.—When the sites for shelters have been selected and the types of shelter decided upon, the sites should be examined to determine what protective measures are required, and in what order of priority. It is particularly important to decide what steps should reasonably be taken before the outbreak of an emergency and what would be necessary to complete the work should an emergency appear imminent. The extent to which work on preparation of shelters should be carried out before the occurrence of an emergency will depend on the local situation and the facilities available. It is, however, of primary importance that plans be prepared in detail and all arrangements made to enable shelters to be prepared on short notice. Such plans should include.

1. Formulation of a general scheme for the protection of personnel.
2. Reconnaissance and evaluation of existing facilities for protection.
3. Examination of existing buildings with regard to protection afforded and best utilization of such buildings.
4. Selection of sites for shelters.
5. Determination of types of shelter.
6. Survey of structural alterations required for each shelter.

7. Survey of construction materials required for shelters and plans for their procurement in an emergency.
8. Survey of equipment required.

When an emergency appears imminent, the following steps should be taken without delay:

1. Execution of construction and shelters and alteration of existing buildings.
2. Purchase of equipment, where necessary.
3. Preparation of shelters for occupation.
4. Final instructions to those for whom shelters are provided.

Protection of Important Establishments.—In considering the problem of protecting plants and establishments in general, it is obviously impracticable to apply the standards of lateral and overhead protection adopted for air raid shelters to all installations of importance and to all structures and utilities of large industrial establishments. The first step, therefore, is to determine what parts of establishments are vital and should have first priority for protection against air bombardment. This decision as to the various vital installations having been reached, the adopted standard of overhead and lateral protection must then be applied, and the latter carried up to a sufficient height to cover all vital parts of the establishment.

Protection of Buildings.—The same general principle of selective protection of vital parts applies to large buildings and structures, where it is manifestly impracticable to attempt to apply protective measures to the whole unit. The obvious exception to this general rule is where the intrinsic value of the building or material contained therein is such as to warrant special treatment and possible extension of protection to the whole building. In deciding on the protective measures to be applied to any particular building, due consideration should be given to the overhead construction and to the protection afforded by neighboring buildings and walls within 50 ft. of the building in question.

Outside Walls.—Where outside walls around vital parts of buildings do not afford the minimum protection required by the adopted standards (see page 96), they must be reinforced. The materials most likely to be available for this purpose are earth, sand, and gravel; and the best method of utilizing them is in the form of a wall or barricade in front of the wall to be reinforced, but separated therefrom by an air space of 2 to 3 ft. The height of the protective wall should be at least 5 ft. above the internal floor level, and the wall should project beyond the sides of the building to give diagonal protection. The average thickness of the wall should be 2 ft. 6 in. The methods of constructing the wall are the same as those described for outdoor barricades (see page 107).

Windows and Doors.—Against bomb blast and splinters, the weakest parts of a building are the openings for windows and doors. It is generally impossible to retain the use of a window and provide full protection against high explosive bombs. Complete protection can be attained only by blocking up the window opening with heavy brickwork or concrete. Partial protection can be obtained by building walls or barricades 2 to 5 ft. in front of the window, with projections beyond the window opening, for protection against diagonal splinters. In such cases, the window glass must also be reinforced, as described on page 105, to prevent flying fragments. Doorways that cannot be eliminated by blocking up can be similarly protected by barricade walls in front of the doorway, with sufficient space between the wall and building to permit entrance, usually about 5 ft.

Roof and Floors.—As a general rule, little can be done to roofs of existing buildings to render them proof against even the smallest sized bombs because of the great additional weight involved in the minimum reinforcing necessary. Thus, it requires at least 4 in. of reinforced concrete to resist penetration by a 2-lb. incendiary bomb and 22 in. of reinforced concrete to resist the smallest (25-lb.) high explosive bomb. Wherever possible, vital parts of buildings should be provided with a roof of at least 4 in. of reinforced concrete. This not only protects against 2-lb. incendiary bombs but may also cause high explosive bombs, equipped with nondelay fuses, to burst before penetrating into the buildings and thus localize their damage. Where the building will not stand the additional load imposed by a 4-in. concrete roof, it may be feasible to build a false roof over vital parts of the building by supporting it on independent columns. This will afford even better protection against nondelay fused bombs because of the intervening air space. It is reported that false roofs of even such light construction as wood and bamboo have been successfully used in China to protect buildings from the effects of high explosive bombs. The degree of protection of false roofs, of course, depends largely upon the size and type of bomb striking the building. For heavy bombs, with delay fuses, the degree of protection is practically nil. With regard to floors and ceilings of ordinary buildings, about all that can be done is to brace and reinforce them over vital rooms so that they can withstand the impact of falling debris if the walls and floors above collapse.

Internal Walls.—Where large numbers of people occupy a building, the interior should be subdivided by splinter-proof partitions or traverses to localize the effects of direct hits.

Protection of Essential Services.—Supplementing provision of shelters for personnel and the reinforcement of buildings for protection of occupants and material, alternate sources of supply should be arranged for water, gas, electricity, and telephone communication that can be promptly brought into use in the event that regular sources of these essential services are interrupted by bomb damage. Arrangements should also be made for the rapid repair of existing facilities and for dealing with damage of machinery and property. Where practicable, duplicates of vital key machinery and special parts and fittings should be kept on hand and stored in a protected place, away from the main buildings of the plant.

Other Methods of Protection.—In addition to provision of shelter for personnel, the reinforcement of buildings, and the protection of essential services, means should also be provided for extricating persons trapped in damaged buildings and for clearing debris from streets and paths. Means must also be provided for storing up and bracing unsafe damaged buildings and for making prompt emergency repairs to damaged utilities, such as electric supply systems, gas and water mains, and sewers. It is also of vital importance that all streets and roads be kept open for traffic and that unexploded bombs be removed and destroyed. The means and methods of protection mentioned in this paragraph will be further discussed in subsequent chapters.

CHAPTER V

PROTECTION AGAINST INCENDIARY BOMBS

Nature of Incendiary Bombs.—In Chap. II, it was stated that incendiary bombs generally range in size from 1 kg. (2.2 lb.) to 20 kg. (55 lb.) weight and that the most dangerous from the viewpoint of attack on cities is the 1-kg. size because of its widespread multiple effects. Thus, a 20-kg. incendiary bomb can start only a single fire, whereas the same weight of 1-kg. bombs may start simultaneously as many as 20 separate fires over an area of several acres, the actual number of fires depending upon the number of bombs that strike inflammable targets. It is, of course, true that the large bomb will produce a more intensive fire center and is thus more certain to ignite a less inflammable target. For this reason, it is probable that the larger sized incendiary bombs will be reserved for special targets of the more fire-resistant type, and the small 1-kg. bomb will be generally used for setting fire to large areas containing many more easily inflammable buildings.

It cannot be too strongly emphasized that the chief danger from air attack with incendiary bombs is the probability of a large number of fires occurring at the same time over considerable areas. Unless these fires are extinguished promptly, they will almost certainly give rise to widespread conflagrations which may produce enormous property damage and seriously dislocate the normal life of the community.

The prevailing type of small incendiary bomb used in Europe during the past few years is the 1-kg. electron bomb, which has already been described in Chap. II. When dropped from a height of 5,000 ft., this bomb penetrates any ordinary roof, including tiles, slate, and corrugated iron, and an underlying plaster ceiling, but probably not a wooden floor below. It is, therefore, apt to remain in an upper story and start a fire, either in the garret or on the first floor below the roof. Moreover, if the burning bomb is not promptly extinguished or removed, it may burn through a wooden floor and possibly through one or more floors below, thus causing a succession of fires.

When the electron bomb strikes an object, the thermite filling is ignited and burns fiercely at a temperature of about 3000°C. for approximately 1 min., melting and setting fire to the magnesium casing, which, in turn, burns less fiercely than the thermite for about 15 min. While the thermite is burning, the combustion reaction is very violent, jets of flame are emitted from the vent-holes of the bomb, and pieces of molten magnesium are often thrown as far as 50 ft. Since thermite contains its own oxygen, it cannot be extinguished by smothering, but the magnesium must receive oxygen from the air or surrounding materials in order to burn. Except for a few ounces in the sheet iron tail and the igniter, the whole of the electron bomb is consumed in the reaction of combustion which makes this type of bomb of very high efficiency.

Incendiary bombs produce a very intense heat. Thermite types, such as the electron, cannot be extinguished with water; on the contrary, the application of water *directly* to the burning bomb is dangerous, for it may cause the bomb to explode and project molten masses of white-hot metal for a distance of 15 to 20 yd. Though smothering with sand is one of the most effective ways of controlling a burning electron bomb, it may not prevent fires when the bomb falls on an ordinary wooden floor or among inflammable materials. The burning action of the bomb on wooden flooring varies considerably. As a rule, 7/8-in. boards are burned through in 4 to 5 min., but occasionally the time is considerably longer. Once a fire has started in a building, it must be extinguished with water, soda acid chemical fire extinguisher, and other ordinary fire-fighting appliances.

Principles of Protection.—In considering the broad aspects of the problem of protecting a community from incendiary bomb attack, it is at once apparent that all possible steps should be taken in advance to reduce the fire hazards that normally exist in buildings and structures in any built-up community. This not only will greatly reduce the incidence of fire from incendiary bombs but will facilitate the dealing with fires that do occur and thus enable householders and occupants of other buildings to extinguish local fires before they spread and become general. It is also obvious that a large number of fires occurring simultaneously in any community cannot be extinguished by the regular fire departments, which are designed to deal only with fires that normally occur in time of peace. Hence, it is necessary that occupants of buildings understand how to control burning bombs and deal with incipient fires, so as to reduce the number of serious fires as much as possible. Also, it is equally important that adequate means be provided to extinguish such fires as get beyond the control of householders and occupants of other buildings.

The methods and means of protection against incendiary bombs may be grouped into two distinct categories: (1) *general precautions to be taken in advance* of an incendiary attack, in order to reduce fire hazards and to ensure prompt detection when incendiary bombs strike a building; and (2) *methods of controlling the burning bombs and dealing with resulting fires*, including the organization and operation of auxiliary fire-fighting services to supplement the regular municipal fire departments.

The best precaution against fires from incendiary bombs is to make buildings as nearly as possible proof against such bombs. This can be done by interposing between the roof and the attic floor of the building a layer of ¼-in. steel plates or a slab of 4-in. reinforced concrete, supported by independent columns. This method of protection, however, is relatively expensive and is seldom warranted, except for especially important buildings and those housing valuable inflammable stores. In the case of buildings with roofs that can be penetrated by incendiary bombs, all unnecessary inflammable materials should be removed, particularly from attics and top floors. The floors of attics should then be covered with noninflammable material, such as (1) a 2- to 2½-in. layer of dry sand, earth, sifted ashes, or foamed slag; (2) sheets of 20-gauge corrugated iron, insulated from the floor by a thin layer of sand or earth; and (3) a ¾-in. layer of asbestos boarding, free from cement, or rock anhydrous plaster. The covering of the floor with any of these materials is of special value in resisting the burning of the bomb through the floor and reducing the risk of the fire spreading. Further to reduce fire risk in the attic, the rafters, joists, and other woodwork should be coated with fire-resisting paint or heavy whitewash.

Since incendiary bombs can be much more effectively dealt with during their incipient stage, early information that such a bomb has fallen on a building is a valuable aid in protection. This requires good observation of the area by lookouts, detailed for the purpose. Only reliable men should be selected for this duty, and they should receive special training in making rapid and accurate reports. In their absence, reports of falling bombs should be made by air raid wardens, police, householders, and neighbors who may observe them. Anyone observing an incendiary bomb striking a building should, of course, immediately warn the occupants and give all possible assistance in dealing with the bomb.

To permit incendiary bombs to be promptly dealt with, arrangements should be made to enable all parts of each building to be reached without delay. This is particularly important in regard to attics and air spaces under roofs; where such spaces are entered through trap doors, suitable ladders or steps should be kept at hand for immediate use. Every small building and each 90-ft. bay of large buildings should be provided with an emergency fire station, comprising a wall locker or closet with the following equipment:

Four 3-gal. buckets (2 sand, 2 water).
1 hand pump, stirrup type, with 30 ft. of ½-in. hose and dual jet-spray nozzle.
1 extension ladder, sufficient to reach attic.
1 long-handled shovel.
1 long-handled scoop and hoe for removing bombs.
1 hand ax.
1 pair heavy gloves.
1 large flashlight or oil lantern.
1 fire-fighting mask.
1 soda acid chemical fire extinguisher.

Every able-bodied occupant of a building, including householders, should be trained to understand how to deal with incendiary bombs and to extinguish fires resulting therefrom. This training should be imparted by actual drills, with each person performing his allotted duties. Drills are especially necessary in large buildings, where elaborate fire-fighting equipment is employed. Since water mains may be broken by high explosive bombs, plans should be made for securing a supply of water in such emergency.

Methods of Controlling Incendiary Bombs.—When an incendiary bomb has penetrated a building, it becomes immediately necessary to: (1) control the bomb and prevent it from burning through the floor or igniting flammable materials in its vicinity; (2) subdue and localize the fire resulting from the bomb, before it gets beyond local control. It cannot be too strongly emphasized that time is of the utmost importance in dealing with incendiary bombs. The situation should, therefore, be tackled as soon as possible after the bomb commences to function, in order to prevent an incipient fire from becoming a conflagration that can be extinguished only by a fire battalion.

There are two general methods of dealing with an electron incendiary bomb: (1) the *sand* method; and (2) the *water* method. In the first method, the bomb is smothered with sand and removed to a safe place; in the second method, a fine *spray* of water is played on the bomb, causing it to react more violently and burn itself out in a shorter time. The sand method is preferable where the bomb can be reached before the surrounding materials have caught fire, and particularly where the surrounding property may be damaged by the sputtering caused by the water method. On the other hand, the water method is more effective where the fire has already spread and there is no danger to surrounding materials from sputtering.

The Sand Method of Control.—As the burning bomb generates considerable heat and glare and throws off sputtering fragments, it may be safely approached within 2 or 3 yd., only in a crouching or prone position, if the operator is protected by a fire-fighting mask or anti-gas eye goggles and heavy gloves. A wet blanket thrown over the operator's back also offers protection from sputtering fragments. About three-fourths of a bucket of sand is dumped on the floor, approximately 2 yd. from the bomb, and with a long-handled shovel the operator places the sand around and on top of the bomb. The operator then shovels the bomb into the bucket on top of the sand remaining therein and covers the bomb with sand from the floor. He then places the end of the shovel under the handle of the bucket and carries it out of the building to a safe place. Instead of using a sand bucket and shovel, a special long-handled scoop and hoe may be employed in removing the bomb. The sand method cannot be used when the bomb has caused a fire so extensive as to prevent close approach, unless special protection can be provided.

The Water Method of Control.—In the usual case, where a bomb falls among inflammable material, a fire will always have started before the scene is reached and therefore close approach to the bomb will be difficult if not impossible. A spray (not jet) of water directed at the seat of the fire is the most effective means of dealing with this situation and will generally be sufficient if applied within the first few minutes after the bomb begins to function. The spray of water increases the rate of combustion of the magnesium by supplying it with extra oxygen, and so the bomb burns itself out in 2 or 3 min., instead of the normal 10 to 15 min. If water is thrown from a bucket or projected in a solid stream upon a burning bomb, it causes violent sputtering and scattering of the molten metal; hence, this procedure is not advisable.

When a bomb has been burning in a room, the heat, glare, sparks, and smoke generated make it unwise to attempt to approach the bomb within about 10 yd. and then only in a prone or crouching position. For this reason a pump capable of projecting a stream of water about 30 ft. (or spray 15 ft.) is required; it should be equipped with at least 30 ft. of hose, so that the person operating the pump may be not less than 60 ft. away from the fire. The pump should be capable of delivering about 2 gal./min., through a ⅛-in. nozzle. Two operators are required to handle this equipment; the first directs the spray, and the second operates the pump. A third person is also very useful to replenish water in the pump bucket and relieve the pump operator.

It is important that the stirrup hand pump be of simple design and rugged construction, so that it is easy to maintain and always reliable in an emergency. The pump should be of the double-action type, with all-metal pistons and valves, capable of delivering about 2 gal./min. when working at 75 strokes per minute. The pressure should be not less than 12 lb./sq. in. on a ⅛-in. nozzle at the end of 30 ft. of ½-in. hose, and the jet should have a range of at least 30 ft. The nozzle should be of the dual-jet type, so that the stream may be changed from a solid jet to a fine spray by simply turning the nozzle.

The first operator, wearing heavy gloves and a mask or goggles, approaches the bomb to a distance within range of the jet, about 30 ft., and first extinguishes any fire in the area surrounding the bomb by playing the jet of water upon it. After the surrounding fire is put out, the operator plays the *spray* upon the bomb until it is burned out. The sputtering from the bomb is usually away from the operator and does very little damage to surrounding objects.

About 6 gal. of water are generally required to subdue the bomb and extinguish the fire in an average room. Therefore, two 3-gal. buckets should be kept constantly filled and placed on the top floor, at a convenient point to the entrance of the attic. If more than two buckets of water is required, the first bucket emptied can be used to fetch more water from the nearest tap.

Another, and even simpler, means of applying water to an incendiary bomb is an ordinary garden hose attached to the nearest faucet in the house. If the hose is sufficient in length to reach any part of the house, particularly the attic, and the municipal water supply is maintained at a sufficient pressure at all times, even when large quantities are being used at the same time to fight fires, then the garden hose will serve the purpose and no hand pump is necessary. The only difficulty about relying upon a garden hose is that, when water is being drawn in large quantities by fire engines from the city mains, it is probable that the household pressure will drop so that a sufficient stream could not be obtained in the attic of a house. Also, there is always the chance that a water main may be burst by a high explosive bomb during an air raid and that the city water supply to the house may fail at the critical time. For these reasons, a hand pump, with buckets of water always available, is much to be preferred to reliance on a garden hose, although obviously a garden hose is better than nothing and should be kept in readiness where hand pumps are not available.

It has been stated above that playing a jet of water *directly* on a burning bomb causes it to sputter violently and is not recommended as a normal practice. However, if the jet of water is large and strong enough, as from a fire hose, it may safely be played directly on the bomb; for although the bomb may react violently and throw pieces of molten magnesium to a considerable distance, it will be consumed in about 15 sec., and the fire hose delivers a sufficient volume of water to deal with any sputtering effects of the bomb.

Chemical fire extinguishers may also be used to extinguish incendiary bombs, provided that they are of sufficient capacity and do not give rise to toxic gases as products of reaction with the burning bomb. The average hand variety of fire extinguisher is of only about 2 gal. capacity, and this is hardly sufficient to extinguish a burning bomb. However, two such extinguishers should be sufficient for the average incendiary bomb.

It is important that fire extinguishers used against incendiary bombs be of the soda acid type, or at least one employing chemicals that do not break down in the presence of heat and liberate toxic gases. Thus, it would be dangerous to use a fire extinguisher employing carbon tetrachloride or methyl bromide, since the first compound generates phosgene, on contact with burning magnesium, and the latter similarly decomposes into toxic bromine gases.

In general the fire started by an incendiary bomb is more important than the bomb itself, but no hard and fast rule can be laid down as to which should be dealt with first. A great deal depends upon the seriousness of the fire, and it is essential that it should not be permitted to get out of control. At the same time, water should be sprayed on the bomb itself as soon as possible to prevent it from burning through the floor. Frequently, it will be necessary first to spray and cool the atmosphere of the room before the seat of the fire can be approached sufficiently close to deal with the bomb and the surrounding fire.

Whenever it is apparent that the fire is getting beyond control, a call for assistance to the fire department should be made without delay. However, the fire department should not be called before such a crisis is reached, as it must always be borne in mind that many serious fires will occur simultaneously during an air raid with incendiary bombs, and the efforts of the fire department should be directed to the serious fires that have got beyond the control of fire-fighting means locally available.

Other Types of Incendiary Bomb.—What has been said above concerning methods of controlling incendiary bombs applies primarily to the small (1-kg.) single-unit electron bomb. There are, however, other types of incendiary bomb that may be encountered and that should therefore be considered in formulating any scheme of defense against incendiary attack. These other types of incendiary bomb were mentioned in Chap. II and the methods of combating them will now be briefly noticed.

In Chap. II, it was pointed out that electron bombs larger than 1 kg. (2.2 lb.) would probably be used only against special targets but that it was possible that the 2-kg. size might be used in indiscriminate bombing. The principal difference between the 1-kg. and the larger sized electron bomb is in their penetrative powers. Whereas the 1-kg. size will penetrate an average roof and underlying ceiling, it will seldom go through the floor below. On the other hand, the 2-kg. bomb will probably penetrate at least one or two floors below the roof, and the larger incendiary bombs will perforate additional floors, in proportion to their weight. Except for this additional penetrative power, the 2-kg. electron bomb can be dealt with by the same methods of control as the 1-kg. size. The larger sizes, however, will generate such great heat and cover so much larger areas with burning fragments that it is necessary that special collective fire-fighting means be provided to combat them. These means will be considered later in this chapter.

Owing to its steel nose, the *multiple-unit* incendiary bomb will undoubtedly penetrate several floors of a wooden building before it bursts and scatters its incendiary units about in the building. The units, however, have small penetrative power after ejection from the main bomb and will probably not go through more than one ordinary partition wall. The problem of dealing with the multiple-unit bomb is, therefore, essentially one of handling several small bombs concurrently. With regard to each incendiary unit, the same methods of control can be applied as in the case of the 1-kg. bomb.

If *petroleum*-filled bombs are encountered, the resulting fire can be smothered with sand or similar material or subdued with water, if care is taken not to spread the oil. As burning gasoline or fuel oil floats on water, care should be exercised not to direct a stream of water on a pool of oil and thus spread the fire. It is better to spray the surrounding material with water until the oil burns out or can be smothered. Chemical extinguishers, particularly those of the fire foam type, are especially effective against burning petroleum.

Fires caused by phosphorus-filled bombs are easily extinguished with sand or water but reignite again on drying. It is therefore necessary after extinguishing a phosphorus fire with water to keep all contaminated material wet until it can be removed. When a phosphorus fire is smothered with sand, the phosphorus should be promptly removed to a safe place and there allowed to burn out. In removing phosphorus in sand or when wet with water, great care should be taken because phosphorus causes dangerous burns on coming in contact with the skin. In spraying burning phosphorus with water, caution is necessary to ensure that no sputtering particles strike the operator. Gloves and a mask or goggles should always be worn.

As stated in Chap. II, it is improbable that sodium or sodium potassium alloys will be used alone as incendiary bomb fillings, but it is not unlikely that these materials may be encountered in conjunction with other incendiary agents, such as phosphorus dissolved in carbon disulfide, and petroleum. The best method of dealing with a sodium or sodium-potassium alloy bomb is to prevent the fire from spreading by the cautious use of a water spray, special care being taken to keep the water away from the bomb itself, and allow the bomb to burn itself out. The bomb may also be smothered with sand and removed to a safe place. If bombs filled with mixtures of sodium and other incendiary agents, such as phosphorus or petroleum, are encountered, water cannot be directed against the bomb itself or any surrounding incendiary liquid. Smothering with sand is the only practicable method of dealing with such fires.

Individual Fire Fighting.—If an incendiary bomb is not dealt with at an early stage and a serious fire is started, the situation will usually call for the resources of the municipal fire department, and it is accordingly important that every person should know the fire organization of his locality and the quickest way of obtaining its assistance. However, since the vast majority of ordinary fires can be extinguished by one or two individuals, properly equipped and acting promptly, it is even more important that everyone understand that a fire resulting from a small (1-kg.) incendiary bomb is an ordinary fire and can be dealt with successfully by individual fire-fighting methods in the vast majority of cases.

The following rules apply to fire fighting in general and to individual fire fighting in particular:

1. Equipment for combating an ordinary fire should be kept on hand in one or more readily accessible fire stations.

2. Anyone discovering a fire should first try to put it out himself, if he can reach it. If he is unable to get at or put out the fire personally, he should at once summon help from the nearest quarter—neighbors, police, Air Raid Wardens, and finally the fire department—if it is apparent that the fire cannot be extinguished by local means.

3. Since the fire resulting from an incendiary bomb is the same as any other fire (except as to the bomb itself), it can be extinguished by water, like any ordinary fire. It is only the bomb itself that requires special treatment.

4. Doors and windows should be kept closed. If the door of a room on fire is left open, the intensity of the fire will be increased, the stairways and passages will act as flues, and the fire will soon

spread all over the building. If it is necessary to open a door, it should be opened only a minimum distance and the person opening it should stand behind the door while doing so, if the door opens toward him. Care should be taken to prevent the door flying open.

5. In searching a burning building, the start should be made at the top of the building and should progress to the comparative safety of the lower floors.

6. By keeping close to the wall, it is often possible to move safely across a floor or staircases that have been weakened by fire.

7. Upon entering a room on fire a crouching or crawling posture should be adopted, for the smoke and fumes are less dense near the floor. Hence, the air will be purer, one can see better, and there is less danger of falling over things.

8. Occupants of a building on fire, who are not required to assist in fire fighting, should be promptly evacuated to a safe place.

9. The possibility of a fire traveling under a floor, in a wall, or up a shaft should not be overlooked, and all such possibilities should be carefully examined before leaving the scene of a fire.

Collective Fire Fighting.—Since an air attack with incendiary bombs is certain to cause a much larger number of fires than can be extinguished by individual fire-fighting means, no matter how well organized, it is essential that collective fire-fighting means be also provided in each community to combat this danger. Collective fire-fighting means comprise one or more of the following fire services, in addition to those normally existing in a community in time of peace:

1. Local fire parties (privately maintained).
2. Group fire parties (privately maintained).
3. Emergency fire organization (publicly maintained).

Local fire parties are small groups of men organized and trained to deal with incendiary bombs and fires beyond the capacity of individual fire-fighting means. Such parties usually consist of 5 to 7 men and are organized to man the particular type of unit fire-fighting equipment employed.

The smallest and simplest fire party consists of 1 leader and 3 men, with equipment for operating a maximum of 300 ft. of fire hose from a fire hydrant without the aid of any pumping apparatus. This type of fire-fighting equipment is usually kept on hand at designated fire stations, near hydrants, either within or just outside of the building to be protected.

In situations where more than 300 ft. of fire hose is operated direct from a fire hydrant without a pump, a hose reel, holding six 100-ft. lengths of hose, is usually employed to facilitate the laying out of the hose. For such equipment, a fire party of 1 leader and 4 men is required. The equipment is usually housed in a special shed or in a fire station in the yard where a small group of buildings are to be protected.

Where fire hydrants are not available, more elaborate equipment and some large parties are required. The party generally varies from 5 to 7 men, depending upon the type of pump employed. As a rule a 2-man manually operated pump is used; this may either be fitted with water containers or require a separate water supply. Where the latter is necessary, a canvas dam is used and is kept supplied with water, carried from the nearest source in canvas buckets. The 2-man pump is equipped with two 60-ft. lengths of 1¾-in. unlined canvas hose, with ¼-in. nozzles, and is capable of delivering an average flow of 8 gal./min., under a pressure of 30 lb./sq. in. For short periods, not exceeding 2 or 3 min., the pump can maintain a ⅜-in. jet of water, with a range of 40 ft., at 40 strokes per minute. This stream of water can extinguish a more serious fire than can a stirrup hand pump.

Group fire parties generally consist of 1 leader and 8 to 12 men, depending principally upon the size of pump and length of hose employed. A small man-handled trailer type of pump, of 120 to 150 gal./min. capacity, supported by two reels, each carrying 300 ft. of 2½-in. fire hose, with 9⁄16- and 13⁄16-in. nozzles, is usually manned by a party consisting of 1 leader and 8 men. For a large man-handled trailer type of pump, of 350 gal./min. capacity, supported by two reels, each carrying 500 ft. of 2½-in. fire hose with 9⁄16-, 13⁄16-, and 1-in. nozzles, a party consisting of 1 leader and 12 men is required. These group fire parties are equipped with the usual firemen's equipment and accessories for towing and operating pumps and fighting fires as independent units. They are generally the largest privately maintained fire-fighting units and, as a rule, are not included in the emergency fire-department organization of the community. Group fire parties may, however, be organized into local detachments, of two or more parties, for the fire protection of an industrial plant or other similar assemblage of buildings. When so organized, they are generally able to handle any ordinary fires that may be caused by incendiary bombs in the area to which they pertain. For an unusually large number of fires occurring simultaneously or where local fires get beyond their control, they must be assisted by the emergency fire organization of the community.

Emergency Fire Organization.—Under normal conditions, the regular fire departments of towns and cities are organized to deal with fires that occur from ordinary causes, and experience under such conditions dictates the size and composition of the force that is required to protect a community of a given size and population. Under war conditions the same, or even larger, number of fires may be expected to occur in any community from non-belligerent causes. When to these are added the additional fires that may be simultaneously produced by an attack with incendiary bombs, it is at once apparent that the regular municipal fire departments cannot cope with the greatly increased task thus imposed. For this reason, it is essential that the regular fire departments of towns and cities in areas subject to air attack be augmented with emergency fire forces. Schemes for this purpose are described in Chap. X.

Protection of Industrial Establishments.—Large factories and other important industrial establishments should be encouraged and assisted in every way to organize and operate their own fire-fighting services. This not only relieves the load on the municipal fire department but ensures quicker and more thorough fire-fighting service to such establishments at a time when they are in the greatest need of such protection.

CHAPTER VI

PROTECTION AGAINST GAS

PRINCIPLES OF PROTECTION

General.—In Chap. II, we discussed the ways and means whereby toxic gas may be employed in modern air attack and the effects produced by the various types and kinds of war gas, particularly as regards the civil population. In this discussion, it was brought out that gas has a vastly greater coverage and more far-reaching effect upon personnel than either high explosives or incendiaries and that its psychological and moral effect is even greater than its actual physiological effects. Protection against gas is, therefore, primarily a matter of public education in the characteristics and effects of war gases and the taking of requisite action in time to be effective. The next most important measures of protection against gas are (1) adequate individual and collective anti-gas equipment; (2) suitable arrangements for cleansing and reclothing personnel contaminated by persistent vesicant agents, such as mustard gas; and (3) means for the rapid decontamination of gas-infected areas, buildings, and materials.

Public Education.—Since the demoralizing psychological effect of gas upon the civil population is almost in direct proportion to its ignorance of the nature and effects of gas, the first step in any effective scheme of protection is the education of the general public on this subject. Nothing will so allay public fear and possible panic as a clear understanding of the powers and limitations of war gases, a knowledge of what to do when subjected to gas attacks, and confidence in the anti-gas equipment and measures of protection furnished by the local authorities. It is accordingly important that sensational newspaper articles that exaggerate the power of gas and dwell upon the horrors of gas warfare should be firmly suppressed, especially in times of emergency when the threat of gas attack is imminent. On the other hand, full and free public discussion, by *qualified experts,* of the real powers and limitations of gas should be encouraged and widely disseminated by all forms of public presentation, such as the press, radio, and motion pictures. With this knowledge as a foundation, the training of the citizenry in protection against gas can best be accomplished by the active workers in the Air Raids Precautions (ARP) services, particularly by Air Raid Wardens. This necessitates the thorough training of such personnel in anti-gas measures of protection as a prerequisite of their use as public instructors. Accordingly, one of the first steps in any scheme of public education in protection against gas is the establishment and operation of a system of anti-gas schools for all active workers in the ARP services. As considerable time is required to pass a sufficient number of persons through such schools to qualify them to act as public instructors, it follows that the schools should be organized and operated in time of peace before a war emergency becomes imminent. The scope and character of instruction to be imparted in anti-gas schools will be further considered in Chap. XV.

Warning.—As protection against gas is largely a matter of taking the requisite action in time, any effective scheme of protection depends upon receiving adequate warning of impending gas attacks. Advance notice of approaching hostile airplanes is transmitted to each threatened community by the Aircraft Warning Service. The warning is then spread in each community by the sounding of sirens, whistles, horns, and other types of alarms. These signals are picked up and further distributed locally by Air Raid Wardens, police, and other workers in the ARP services. Characteristic local signals must be given to indicate the presence of gas, such as the sounding of rattles or the ringing of special bells.

In addition to this preliminary warning of approaching hostile aircraft, information of their actual arrival over any area is obtained by special lookouts detailed for the purpose at strategic points. Only reliable men should be selected for duty as lookouts; they should then be trained in making rapid and accurate reports of falling bombs or sprays and in the recognition of gas. They should also have a thorough knowledge of the ARP organization and the means of communication available. When gas has fallen on a community, its presence is further indicated by the use of chemical detectors and the marking off of contaminated areas (see page 133).

Anti-gas Equipment.—The first line of defense against gas is *individual protection*, involving the use of personal anti-gas equipment, such as the gas mask and protective clothing. The second line of defense is *collective protection* which comprises the use of gas-proof shelters and accessory appliances. Accordingly, anti-gas equipment is divided into two general categories: individual equipment and collective equipment, in accordance with the principle of protection.

As regards the protection of the civil population against air gas attack, the performance requirements of *gas masks* differ in degree, depending principally upon the status of the individual, respecting his function in the community. If the individual has no duties to perform during an air gas attack or his duties are such that he can temporarily suspend them and seek shelter during such an attack, he requires only the minimum of mask protection, for such time as is required to reach a gas shelter. For such people, who constitute the bulk of the population in any community, the simplest and least expensive type of mask is all that is necessary. This type is generally known as the *civilian* gas mask.

For individuals who are *active* workers in the ARP service, police, and fire departments or who are keymen in public utilities and industry and, in general, for all persons who may have to continue to work at their posts of duty in gas-infected areas, a more elaborate and expensive gas mask is required. This is called, in England, a *civilian duty* gas mask and affords protection intermediate between the civilian mask and the military mask.

For persons who are required to remain at their posts of duty regardless of conditions arising from hostile action and who are expected to perform heavy duties in strong concentrations of gas, the best possible mask protection is required. Such personnel are equipped with the *general service* gas mask.

Protective clothing is necessary to protect the body against the action of vesicant gases, since these gases will penetrate any ordinary form of clothing, including leather and rubber gloves and boots, and burn the skin of the wearer. Like masks, several types of protective clothing are provided for individuals, depending upon their duty status. Protective clothing affording the minimum protection, such as light impermeable capes, coveralls, and overcoats, is all that is normally required by the average citizen who may take shelter during air attacks. For those whose duties preclude taking shelter during air attacks, two types of anti-gas duty clothing are usually issued. The *light* anti-gas clothing is used by those who may normally be exposed to both vesicant liquids and vapors for limited periods and generally in lower concentrations; the *heavy* type is for use by those whose work is in high concentrations of vapor in areas grossly contaminated by liquid vesicant gas and who may be thus exposed for long periods. The various types of mask and protective clothing will be further described later in this chapter.

Collective protection against gas is generally effected by the use of gas shelters which consist essentially of an enclosed space, virtually air-tight, which is supplied with pure air, drawn in from the outside through a chemical filter by means of an air pump. Gas shelters are not, as a rule, constructed separately from high explosive bomb shelters. On the contrary, the two are usually combined in the same structure, by gas-proofing the splinter-proof shelter, as an additional measure of protection. The gas-proofing of splinter-proof shelters consists merely in stopping up extraneous air leaks and providing the shelter with a supply of gas-free air drawn in through a chemical filter. In some types of deep underground shelter the air in the shelter may be chemically purified and recirculated, the shelter being thus rendered independent of external air supply for many hours.

Gas Cleansing Centers.—Stations designed and equipped for the treatment of unwounded persons who are contaminated with vesicant gas are known as *gas cleansing centers.* Since contaminated persons must be promptly treated to prevent serious casualties, gas cleansing centers should be provided in each populated area on a scale that will ensure the possibility of treatment of all personnel within 10 min. of contamination. This requirement conditions both the density of location and capacity of these centers. In general, gas cleansing centers contain suitable arrangements for undressing, cleansing, and reclothing contaminated persons (see page 227).

Decontamination.—Since contaminated ground, buildings, and material in gas-infected areas must be quickly decontaminated in order to prevent widespread injury to personnel in such areas, decontamination depots must be organized and operated in each community subject to air gas attack. The principle of decontamination is simple and consists essentially in applying a gas-neutralizing agent to all contaminated surfaces as soon as possible after contamination. Each decontamination depot is, therefore, provided with suitable personnel and equipment to carry out decontamination operations and functions as a headquarters for this work in each district (see page 224).

INDIVIDUAL PROTECTION

General.—Individual protection against gas comprises the following:

1. The detection and recognition of war gases.
2. Knowledge of the characteristics and effects of the various kinds of war gas.
3. General anti-gas precautions to avoid becoming a gas casualty, especially for those who must work outdoors in a contaminated area.
4. Protection of the eyes and lungs, including use and care of gas masks, fitting, test, and inspection of masks, and ability to carry on normal work when masked.
5. Protection of the body, including knowledge of protective ointments, use of anti-gas clothing, and manner of dressing and undressing to avoid injury from contamination.
6. Knowledge of the methods of self-cleansing when a cleansing center is out of reach.
7. Anti-gas treatment of individuals.

Detection of Gas.—As applied to war gases, detection involves the recognition of the presence of gas and the identification of its type. The presence of gas may be detected by (1) the sense of smell, (2) its immediate irritant effects, (3) its visible signs, and (4) chemical detectors (see Table III, page 50).

Since most war gases betray their presence by a distinctive smell or a characteristic irritant effect on the nose and throat or are visible in the form of a cloud or liquid splashes on the ground, they may usually be detected by the senses, particularly the sense of smell. Some gases in low concentrations, however, may elude detection by any human faculty, and can only be discovered by chemical means.

Because of their slight and temporary incapacitating effect, *tear gases* will probably not be used alone in air gas attacks on cities. However, tear gas may be used in conjunction with other types of gas, chiefly to mask the presence of the latter. If present, tear gases are easily detected on account of their immediate lachrymatory effect upon the eyes. However, many tear gases consist of dark-brown persistent liquids that must not be mistaken for mustard or other persistent vesicants.

As *respiratory irritant gases* (toxic smokes) are practically colorless and odorless in average concentrations outdoors, the first indication of their presence will be an irritation of the nose and throat and sneezing. These effects are characteristic and so distinctive as not to be confused with any other types of gas.

Lung injurant gases are also easily detected by their characteristic odors. *Phosgene* is the most important of these gases; it has a pronounced smell of newly cut hay or corn. It also forms a thin cloud in moist atmosphere but otherwise is colorless. Rapid detection is essential to prevent injury from phosgene, and training with dilute concentrations is generally necessary to ensure detection by the sense of smell. Phosgene may also be detected by chemical detectors.

Vesicant gases, such as *mustard* and *lewisite,* can also be detected by the sense of smell, although the former may be present in low concentrations that elude the sense of smell and yet are incapacitating upon prolonged exposure. Thus, the lowest concentration of mustard gas that can be detected by the keenest sense of smell is approximately 0.013 mg./liter, and a consideration of 0.010 mg./liter will cause conjunctivitis after 1 hr. exposure. Moreover, after a short time the sense of smell becomes dulled, and low concentrations of this gas may not be detected.

Though mustard gas is by far the most difficult gas to detect, it can nevertheless be recognized by (1) the sense of smell; (2) visible signs; and (3) chemical detectors. The characteristic odor of this gas is suggestive of horse-radish, onions, or garlic; but the smell is faint, and many persons cannot smell it except in high concentrations. Its odor is also readily masked by the odors of other gases. For these reasons, much effort has been expended in recent years in devising a chemical detector for mustard gas.

In liquid form, mustard gas varies in color from dark brown to light straw, depending upon the impurities present. On dry ground the liquid appears as a wet, oily patch which is easily seen. The pale liquid is, however, difficult to see on vegetation. On wet surfaces, it generally has an iridescent sheen, similar to that of oil. In vapor or gas form, mustard is colorless and can be detected only by its odor or by chemical detectors. Unlike mustard gas, lewisite is readily detected by its strong odor of geraniums and its irritant effect on the eyes and nose.

Chemical detectors for indicating the presence of war gases, and particularly mustard gas, have been developed in recent years and are regarded as generally satisfactory, except for the detection of mustard *vapor.* Chemical detectors are usually based upon the production of a characteristic color reaction whenever the detector compound is brought into the presence of the gas to be detected. The chemical detector may be in the form of a paint, a powder, or a liquid to impregnate cloth or paper.

In the form of paint, the detector may be applied to objects, such as wooden indicator panels about 18 in. square, that show a characteristic color stain on contact with a liquid vesicant gas. These panels, when brought in contact with suspected contaminated surfaces, will thus indicate whether liquid vesicant gas is present or not. The detector paint may also be applied to buildings, lampposts, letter boxes, and other objects near the ground, so that if any liquid war gas is sprayed or falls in the area it will be shown as stains upon the painted surfaces.

In the form of powder, the detector is applied to any suspected contaminated surface and reveals the presence of liquid gas by a characteristic color change.

In the form of a liquid, the detector is generally employed to impregnate outer clothing or cloth indicator strips, worn around the arm, which disclose the presence of gas by a color stain on the cloth. The liquid detector may also be used to impregnate test paper which is then employed to indicate the presence of vesicant gas by a color change.

The best chemical indicator produced to date is a grayish white powder, developed in Czechoslovakia, which it is claimed indicates mustard gas by a red reaction color, lewisite by an orange color, and phosgene by a deep-blue color. It does not react to tear gases or petroleum oils. It is further claimed that this powder will reveal the presence of mustard gas in concentrations as low as 50 mg./sq. m. of contaminated surface.

The chief difficulty with chemical detectors as developed to date is their inability to indicate the presence of mustard *vapor,* apart from the liquid; and since the most prevalent danger is from the vapor, it is apparent that this constitutes a serious limitation in the usefulness of chemical detectors. This limitation and the fact that many chemical detectors are not selective between mustard gas and tear gas, or even lubricating oil, render these detectors only an aid to and not a substitute for other methods of detection.

There is a pressing need for a more reliable, selective, and sensitive chemical means of detection than any produced thus far, and there is little doubt that substantial improvement in this field will be achieved in the near future, although the problem is admittedly a most difficult one to solve.

Knowledge of War Gases.—The characteristics and effects of the various kinds of war gas were described in Chap. II (see page 48). It is, of course, essential that anyone liable to exposure to gas should have a good practical knowledge of the characteristics and effects of war gases, in order that he may know how to avoid becoming a casualty. This knowledge can best be imparted through a system of public instruction by qualified instructors who should be graduates of special gas schools (see page 128).

General Anti-gas Precautions.—The risk of gas injury will be reduced to a minimum by observance of the following precautions:

1. Everyone should always carry a gas mask in time of war if residing in a locality liable to attack.
2. Immediately upon hearing an air raid warning, indicating use of gas, everyone should put on his mask at once and seek the nearest gas-protected refuge room or shelter, unless his public duty requires him to work outdoors, in which case he should remain masked until the "All Clear" signal is heard.
3. Everyone, on hearing an air raid warning, *not* indicating the use of gas, when his duty prevents taking cover should always have his mask ready to put on at once and his protective clothing, if necessary.
4. No one should leave a gas-protected refuge or shelter without first ascertaining whether gas is still present in the vicinity.
5. No one should work in the vicinity of persistent vesicant (*e.g.*, mustard) gas without complete coverage with protective clothing and mask.

When gas is used during an air raid, it must be borne in mind that the danger may remain for a considerable time after the raiders have passed. Hence, when the signal "Raiders Passed" is given, it must be realized that this message simply means that the hostile aircraft are no longer overhead and that it is not safe to leave a gas-protected refuge or shelter until the "All Clear" signal is given. If gas remains in the streets after a raid, the general public should not leave gas-protected shelters until the gas has dissipated or has been neutralized by decontamination.

Upon being unavoidably caught in the streets during an air raid in which gas is used, the mask should be donned at once and the nearest *overhead* cover sought, in order to avoid possible falling spray. When the raiders have passed and gas is still present, the nearest gas-protected shelter should be entered until the area is cleared of gas.

Those whose individual detectors indicate, by color change, that their clothing has become contaminated while seeking cover, should upon reaching a gas-protected shelter, immediately remove their clothing and rub all exposed skin with anti-gas ointment. The contaminated clothing should be placed outdoors until decontaminated.

In walking through a contaminated area, care should be exercised to avoid all splashes or pools of liquid lying about and not to touch walls of buildings, fences, lampposts, and other objects in the street that may be contaminated. Since leather shoes are quickly penetrated by mustard gas, they should be removed as soon as possible upon reaching shelter and placed outdoors until decontaminated.

Members of ARP services and others whose duties require them to enter contaminated streets and areas should avoid heavily contaminated spots as much as possible. Thus, they should keep to the windward of bomb craters and splashes and pools of liquid and avoid stepping on earth and debris that may be contaminated. In such situations the mask should always be worn and not removed until the wearer has tested the air by inserting the fingers between the facepiece and the cheek and sniffing gently. Careful training will enable persons readily to appreciate when danger exists and to take the necessary steps to avoid becoming a casualty.

Protection of the Eyes and Lungs.—Gas masks are designed to give protection to the eyes and lungs against all types of gas that are likely to be used in war. They do not, however, afford protection against industrial gases, such as carbon monoxide, ammonia, petroleum vapor, and fumes encountered in fire fighting. For each of these industrial gases a special type of commercial mask is required; the war masks should never be used for such purposes.

It must also be borne in mind that, although war masks afford satisfactory protection to the eyes and lungs against vesicant vapors, they do not extend protection to other parts of the body; therefore, protective clothing is always required for complete protection against vesicant agents.

As previously indicated in this chapter, war masks are generally provided in three types, depending upon the degree of protection required: (1) the civilian mask; (2) the civilian duty mask; and (3) the general service mask.*

The *civilian mask,* for use by the general public, protects the eyes and lungs of the wearer against any known war gas and should always be worn when gas is present and a gas refuge or shelter is not available. As the life of a civilian mask is limited, civilians not required to work outdoors during air gas attacks should habitually take refuge in a gas shelter during such attacks and thus save the useful life of their masks. Gas shelters also afford better protection against prolonged exposure to vesicant agents than light civilian protective clothing.

The civilian mask consists of a tin canister filled with materials to filter and absorb toxic gas and a facepiece to cover the eyes, nose, and mouth (see Fig. 20). The facepiece is composed of sheet rubber with a large eyepiece of noninflammable transparent material, such as cellulose acetate or the like. The canister is attached to the facepiece by means of a strong rubber band, and the inspired air is drawn in through the canister which removes the toxic gas. A check valve on the inner side of the canister causes the expired air to pass out between the facepiece and the cheeks of the wearer, its discharge through the canister being thus prevented.

The mask is held in position over the face by means of three straps, which are adjustable to fit comfortably on the head, and is supplied in three sizes of facepiece, according to the size of the wearer's face. The mask must be fitted to the face of the individual and should be tested for gas-tightness in a gas testing chamber. In England, the civilian mask when issued becomes the personal property of the individual who is responsible for its use and care. This mask is not provided with a carrier but is issued in a strong cardboard box in which it is habitually kept when not in use. The design of civilian masks and the policy governing their issue to the public vary in the different countries.

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* British classification.

The canister of the British mask consists of a cylindrical tin container holding activated charcoal to absorb toxic gases and is provided with a particulate filter for removing toxic smokes and dusts (see Fig. 21). The contents of the canister gradually become exhausted when used in gas concentrations, the life depending upon the strength of the concentration and the time of exposure. The life of the canister is, however, ample for the conditions under which it will be used by the general public.

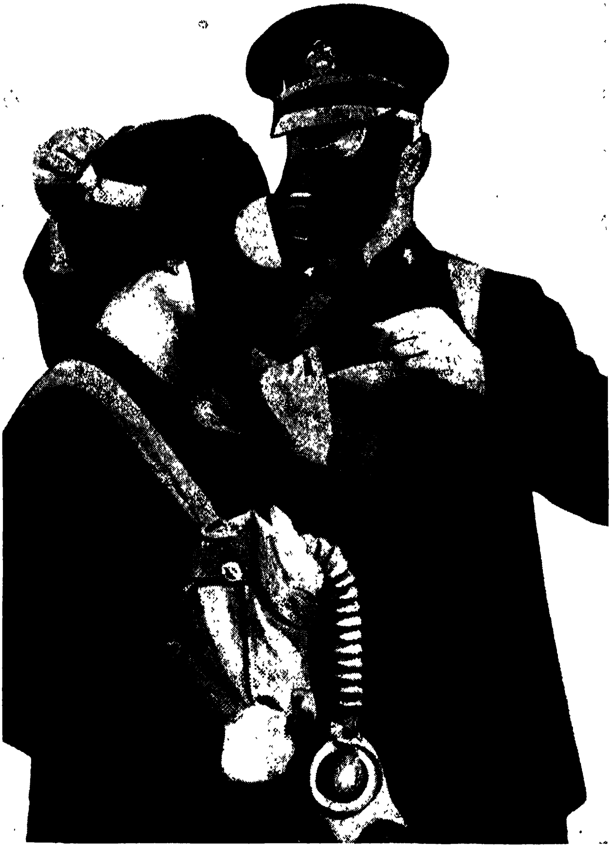


FIG. 20.—Civilian gas mask (British).

A special small sized child's gas mask, of the same general pattern as the above-mentioned civilian mask for adults, is required for children below four to five years of age; for infants under two years old, a gas helmet or hood is considered most suitable (see Fig. 22).

During the present war, the British Government has issued a civilian gas mask to every man, woman, and child in the British Isles. These masks are furnished without cost to the individual and are the property of the Government. The persons to whom they are issued are responsible for their care and for any loss or damage.

The *civilian duty mask,* for members of the ARP services and others who may be called upon to carry on their normal duties in the presence of gas but are not likely to be continuously exposed to the highest concentrations, is basically similar in design to the civilian mask in that the canister is attached directly to the facepiece.

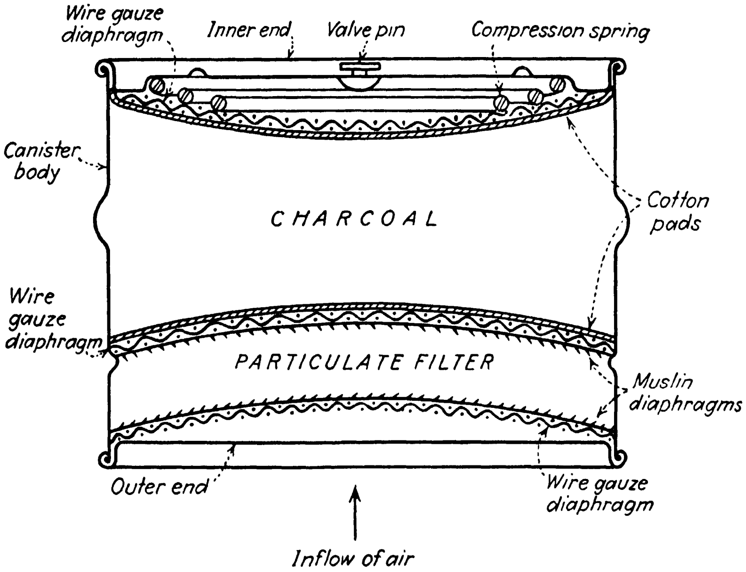


FIG. 21.—Civilian mask canister (British).

The facepiece of the civilian duty mask is made of rubber, molded to fit closely to the face, and is of heavier material to withstand harder wear. It has an outlet valve and a stud on the left cheek to which a microphone can be attached to facilitate telephone conversation. The facepiece is fastened tightly around the end of the canister by means of a metal band and is held in position on the face by adjustable elastic bands passing over and behind the head (see Fig. 23). It is equipped with circular eyepieces of plain glass, held in metal rims by detachable screwthreaded ferrules. Each eyepiece is backed with a thin removable disk of gelatine-coated material to prevent dimming from the breath.

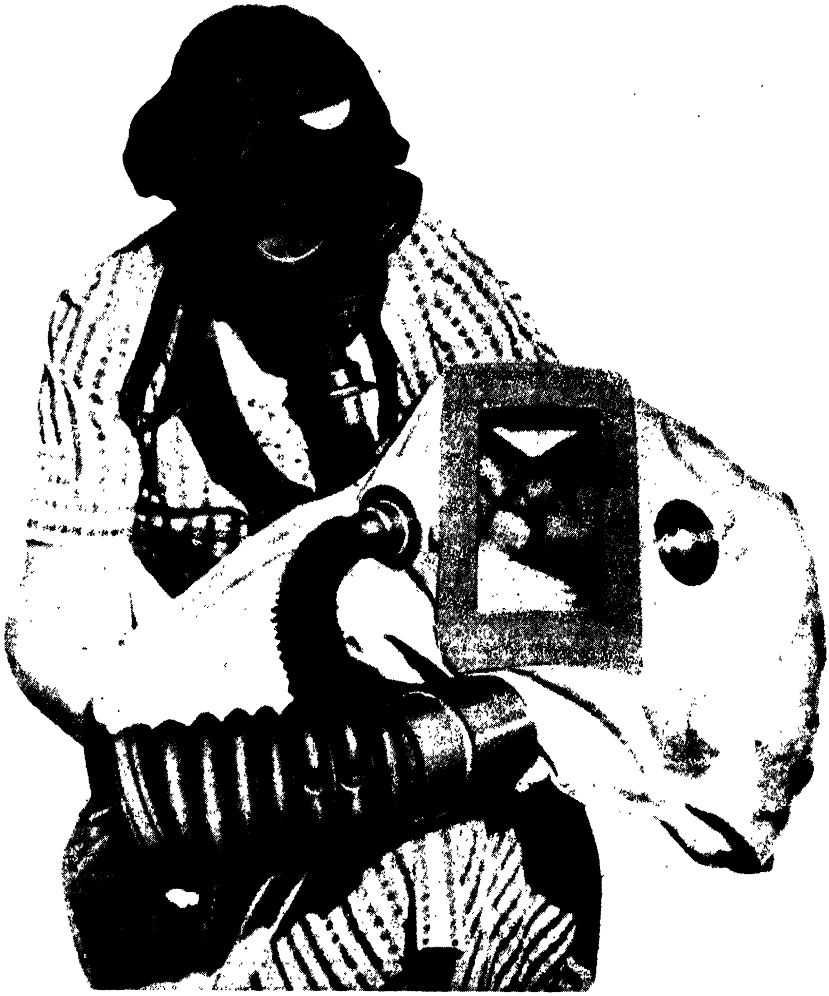


FIG. 22.—Gas mask for infants (British). (Chema Mfg. Co., London.)

The canister of the civilian duty mask is identical with that of the civilian mask, except for the charcoal which has a higher degree of activation and hence a longer life in use. When not in use, the civilian duty mask is carried in a small canvas carrier slung under the left arm.

The *general service mask* is the military type, as issued to the fighting services, and is furnished to those members of the ARP services whose duties may involve their working in high concentrations of gas (*e.g.*, police, first aid parties, and decontamination squads). The general service mask affords the maximum of comfort and protection to the wearer and is more durable in hard usage than the civilian duty mask. It differs in appearance from the civilian duty mask chiefly in that the canister is not attached directly to the facepiece but is carried habitually in the canvas carrier and is connected to the facepiece by a length of flexible rubber tube.

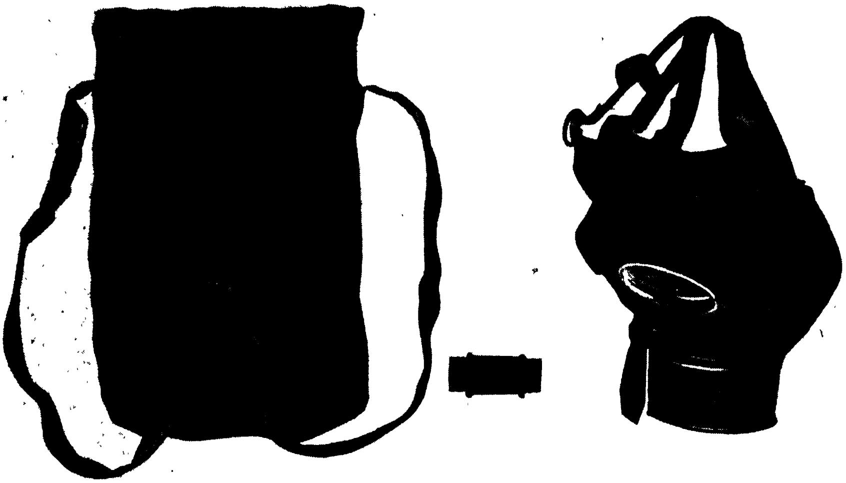


FIG. 23.—Civilian duty gas mask (British).

The facepiece is made of heavy rubber, molded to fit closely to the face and afford maximum vision through the eyepieces. It is held in gas-tight contact with the face by adjustable elastic bands passing over and around the back of the head (see Fig. 24). The eyepieces consist of circular disks of splinter-proof glass which may be removed by unscrewing to permit decontamination of the facepiece by boiling it in water.

The outlet valve is a rubber disk housed in a metal valve holder which connects the facepiece to the hose tube. The air in entering the facepiece passes across the eyepieces and thus reduces dimming from exhaled air. The outlet valve discharges expired air directly into the outer atmosphere and is so designed as to have considerable sound-transmitting action to render the speech of the wearer audible. The hose tube is made of rubber covered with stockinet and is corrugated to give flexibility and prevent collapsing when bent.

The canister of the general service mask is of tin, somewhat larger than the civilian duty canister, and is generally cylindrical in shape, with oval cross section. It affords complete protection against all known war gases and toxic smokes.

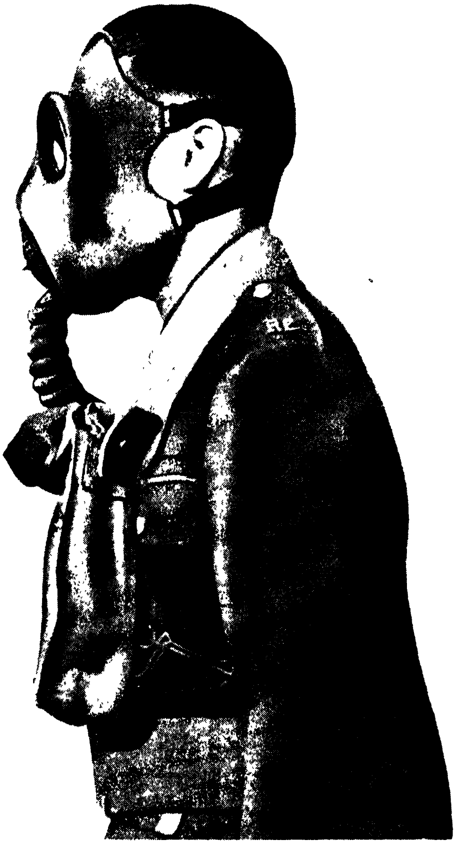


FIG. 24.—General service gas mask (British).

The carrier of the general service mask is of waterproof canvas and is adapted to be slung under the left arm when not in use and on the chest when in use.

As the wearer's life may depend upon the integrity of his mask, it should always be maintained in good order and frequently inspected for defects and wear and tear. It should also be carefully fitted to the wearer's face each time it is put on and tested for gas-tightness.

In addition to ability quickly to put on and adjust a mask, it is necessary that those whose duties require them to work outdoors during air raids should be able to carry on their normal duties while masked. Often, this ability can be acquired only by frequent practice, particularly where heavy manual work is involved and deep breathing is required.

Protection of the Body.—As has already been stated, vesicant gases attack any part of the human body to which they have access. *Liquid* vesicants, such as mustard and lewisite, will penetrate any *ordinary* form of clothing, including leather and rubber, and will burn the skin of the wearer. The *vapors* of these agents will also penetrate ordinary clothing and cause injury if the time of exposure is long enough or the concentration sufficiently high. However, a certain length of time is required for vesicants to penetrate even ordinary clothing, depending upon the natural resistance of the material. In general, the denser the composition of the material, the longer the time required for penetration. Thus, ordinary cloth is readily penetrated by the liquid in a few seconds and by the vapor in a few minutes. Leather and rubber may be penetrated by the liquid in a period varying from several minutes to as many hours, depending upon the thickness and density of the leather or rubber, the amount of liquid in contact therewith, and the temperature. For this reason, ordinary clothing is of some protective value in that it delays penetration to some extent and therefore the full effects of any contamination are not immediately produced on the skin. It is accordingly of the utmost importance that contaminated clothing be removed *as quickly as possible*, and the skin thoroughly scrubbed with soap and water; the hotter the water the better. In this way, injury may be much reduced or entirely avoided if action is taken in time.

Of ordinary commercial articles of apparel, it has been found that oilskin (made from various textiles by treating them with certain drying oils, such as linseed oil) and heavy rubber garments, including boots, furnish the best protection against vesicant agents, and these materials have been widely adopted for this purpose. Though such garments do not afford *absolute* protection against liquid vesicants, in that they will be penetrated after a number of hours' exposure, this penetration time is definitely determined for each type of garment, and, if not exceeded, the protection afforded is adequate. By decontaminating such apparel periodically after each period of exposure to vesicants, it may be safely used for long periods of time.

In general, the time required for a liquid vesicant to get through an oilskin or rubber material varies inversely with the temperature; *i.e.*, the hotter the weather, the quicker the penetration. The time of penetration will also vary with different grades and thicknesses of material. Strong oiled wigan gloves will, when new, keep out liquid mustard gas for at least 4 hr. even in hot weather. Oilskin garments are decontaminated by boiling in water which reduces their time of penetration about 1 hr. for each boiling.

The resistance of leather to penetration by liquid vesicants can be greatly increased by coating its outer surface with an impermeable liquid coating composition, or daub, in which is incorporated a reagent to neutralize the vesicant. Leather shoes and gloves, so treated, afford satisfactory protection if periodically decontaminated after exposure to vesicant agents.

The chief disadvantage of the impermeable apparel, mentioned above, is its nonporous nature which causes the heat and perspiration to be retained inside the clothing. This greatly increases fatigue and exhaustion of manual workers, especially in hot weather. As a rule, men cannot work more than 2 hr. at a time in impermeable protective clothing, and in hot weather even less. This is a very serious limitation in the use of this type of protective clothing, and much work is being done in an effort to produce a permeable garment that will resist vesicant liquids and vapors. It is, of course, possible to impregnate cloth and even rubber with certain chemicals that will neutralize vesicant agents and at the same time permit the percolation of air through a porous material, such as cloth. Though such impregnated materials will protect against vesicant *vapors*, they do not afford sufficient protection against vesicant *liquids*, owing to the extremely short time required for such liquids to soak through the cloth.

The problem of producing satisfactory protective clothing is admittedly a most difficult one; and though it will undoubtedly be solved in time, the principal means of body protection in general use today is still the impermeable garment of oilskin or rubber.

In England, three types of anti-gas garments have been adopted as follows:

1. *Anti-gas cape*, made of light oilskin and put on over all outer clothing and equipment, including the gas mask. It is held in place by two straps, passing from the back, over the shoulders, and underneath the armpits. These capes are provided to give protection against vesicant sprays and do not protect against vapor. They are intended primarily for citizens caught in the streets or open places during an air raid in which gas sprays are used, and they afford sufficient protection against falling sprays to enable a person to reach a gas shelter in safety.

2. *Light anti-gas suit*, which consists of

   a. Light oilskin jacket.
   b. Light oilskin trousers.
   c. Oilskin fabric gloves.
   d. Rubber knee boots.
   e. Oilskin helmet curtain.

   This suit is provided for persons not required to work for long periods in heavy concentrations of gas but who nevertheless may require protection from both vesicant liquid and vapor.

3. *Heavy anti-gas suit*, which consists of

   a. Heavy oilskin jacket.
   b. Heavy oilskin trousers.
   c. Oilskin fabric gloves.
   d. Oilskin fabric hood.
   e. Rubber knee boots (see Fig. 25).

   This suit is furnished to certain ARP service personnel who may be required to carry out their duties in the heaviest concentrations of gas in an area badly contaminated by liquid vesicants, such as decontamination squads and rescue parties.

Whenever there is danger from vesicant vapor, the mask and light anti-gas suit should be worn. Whenever heavy concentrations of vesicants in liquid or vapor form are encountered, the heavy anti-gas suit will be required. However, owing to the exhaustion caused by the heavy suits, they should not be worn unless the conditions make it essential.

In putting on a complete anti-gas unit, it is necessary first to remove ordinary clothing and change into other underclothing. The order of dressing in full anti-gas clothing should be as follows: (1) underclothing and socks, (2) trousers, (3) boots, (4) jacket, (5) gas mask, (6) gloves, and (7) steel helmet with anti-gas curtain. After each work period, contaminated anti-gas clothing should be removed by another man, who is himself protected by such clothing, in the following order: (1) helmet or hood, (2) gloves, (3) mask, (4) jacket, (5) trousers lowered, (6) boots, (7) trousers removed,

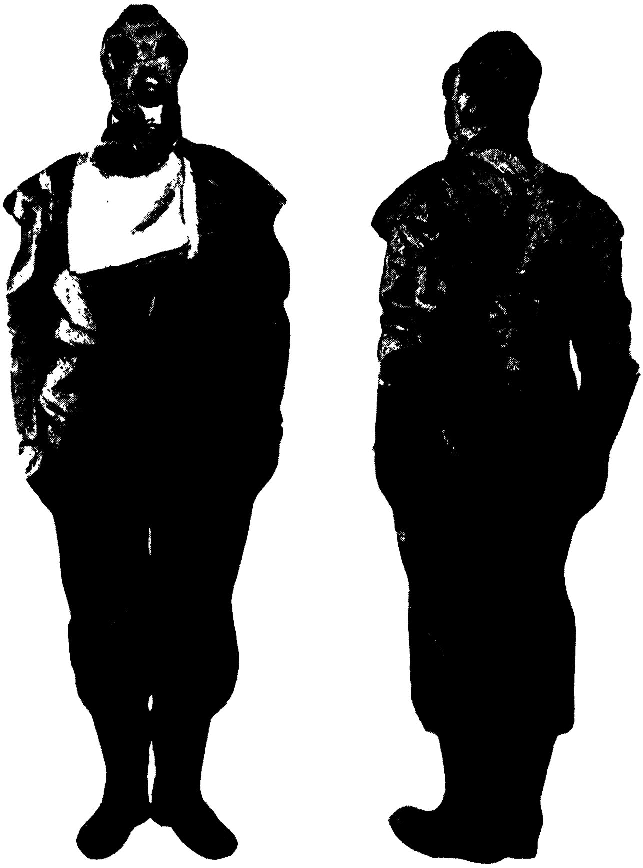


FIG. 25.—Heavy anti-gas suit, without hood (British).

and (8) underclothing. Each article as removed should be placed in a separate covered bin, until decontaminated.

Methods of Self-cleansing.—Where a gas cleansing center (see p. 130) is not accessible within 10 min. after contamination, persons contaminated should first apply anti-gas ointment to exposed skin and then seek the nearest building where soap and water are available. Contaminated clothing should be left outside the door and the authorities informed of its whereabouts so that it may be collected for decontamination. As soon as clothing is removed, all exposed skin should be vigorously scrubbed with soap and hot water. If at home, the entire body should be so treated in the bath-tub.

Members of ARP services who have been on duty in a contaminated area should undergo cleansing treatment, as a routine precaution, whether or not they believe themselves to have been exposed to gas. When coming on duty, these men should remove their own clothing and underclothing and put on anti-gas clothing provided for them; and when coming off duty, they should discard their duty clothing whether they think it is contaminated or not. They should then wash thoroughly with soap and hot water before putting on their own clothes again. Duty clothing should be tested for contamination after removal at the end of each tour of duty and, if found contaminated, should be segregated and decontaminated. There should be a cleansing place available for all members of ARP services where they can cleanse themselves when coming off duty. Where convenient, this should be the station or depot out of which they operate. Alternatively, a cleansing station for such workers may be provided for groups operating in any neighborhood. Arrangements must be made for decontaminating infected clothing at decontamination centers (see page 130).

Anti-gas Treatment of Individuals.—As the facilities for removing vesicant gases from personnel must in general be separate and distinct from those for dealing with gas-infected areas, buildings, and materials, it is customary to refer to the removal of bodily contamination of persons as "anti-gas treatment," clearly to distinguish it from the removal of contamination from material objects which is generally termed "decontamination." With regard to the treatment of persons contaminated by vesicant vapor or liquids, it cannot be too strongly emphasized that *quick action* is of the utmost importance.

The first step is to remove contaminated clothing and dispose of it in such a way that it does not become a source of danger to others. If the face has been exposed, the eyes should be washed and the nose and throat rinsed with a saturated boric acid, weak sodium bicarbonate, or common salt solution. Vapor burns on the skin can be prevented, or at least greatly reduced in severity, by thorough scrubbing with hot soap and water *immediately after exposure.* As vesicant gases usually penetrate the skin within 5 min. after contact, areas wet with vesicant liquids should be *at once* repeatedly swabbed with a solvent, such as kerosene, gasoline (not containing tetraethyl lead), any oil, alcohol, or carbon tetrachloride. Cleansing the exposed parts with such solvents will facilitate the removal of all traces of the gas.

Alternative treatments for skin contaminated with liquid vesicants is to rub the infected area with an ointment composed of bleaching powder incorporated in vaseline or with a paste of bleaching powder and water and then wash the affected parts with hot soap and water. Fresh cloths should be used in treating contaminated parts and care exercised to avoid spreading the contamination. Contaminated cloths should be burned after use. Fresh, uncontaminated clothing must be supplied where necessary.

The foregoing anti-gas treatments should be undertaken by the public at home or place of work, if it can be so done immediately. If not, recourse should be had to the nearest first aid post (see page 193) if no quicker means are available or if the contamination is severe. Persons who treat themselves at home should remove their contaminated shoes and clothing before entering the house.

COLLECTIVE PROTECTION

General.—Means and measures of protection against gas that apply generally to a group of persons, as distinguished from those means and measures that pertain solely to an individual, are termed *collective protection* and comprise the following:

1. Arrangements for sounding gas alarms to warn the general public of the presence of gas.
2. Means for the detection and identification of gas.
3. Provision and use of gas-proof shelters where personnel may take refuge in a gas-free atmosphere during gas attacks.
4. Removal of gas from buildings and enclosed spaces.
5. Marking off and excluding the public from contaminated areas and buildings.

6. Decontamination of ground, buildings, clothing, and equipment.
7. Public gas cleansing centers.
8. Precautions with reference to food and water.
9. Provision of an organization to supply and issue protective equipment and to supervise anti-gas training of personnel and the conduct of protective measures.

Gas Alarms.—The general scheme of warning the public of the presence of gas was outlined on page 128 of this chapter. As it is impossible to tell from a general air raid warning whether or not gas is dropped, a special gas alarm must be given by someone on the spot after the presence of gas is detected. Air Raid Wardens and police will generally be the first qualified personnel available, and they are accordingly the agents utilized in England for this purpose. The instrument adopted for warning the public of the presence of gas is the police rattle, and a hand bell is used to indicate the end of gas danger in the locality.

Any warden or policeman who detects gas in his sector will sound his rattle around the streets of his sector. Wardens and police in neighboring sectors *down-wind* will then proceed toward the sound to the boundaries of their sectors and, when they have ascertained the travel of the gas, will similarly spread the alarm, but not beyond the range of danger.

When the danger of gas has ceased in a sector, the wardens and police will notify the public of this fact, by ringing the hand bells provided for this purpose. Since gas may linger in dangerous concentrations for some time after hostile raiders have passed, the public should be impressed with the fact that streets are not safe for traffic until the local gas warning has been canceled by the ringing of the gas signal bells.

Gas Detection and Identification.—The means and methods of identification of war gases were mentioned on pages 131 to 134 of this chapter. In order to provide a system of gas detection and identification, it is necessary to organize and operate a Gas Detection and Identification Service, as a part of the Air Raids Precautions Department (ARPD) (see Chap. XIII, page 231).

Gas-proof Shelters.—Gas-proof shelters should be regarded as the primary protection against gas of those whose duties do not compel them to work outdoors or remain in an exposed place during air raids. They are also a valuable secondary protection for active members of the ARP services when not on duty, for they afford accommodations where such personnel may rest, sleep, and eat in a gas-free atmosphere. Since gas may, and probably will, be used in conjunction with high explosive bombs in air attacks upon cities, gas shelters and splinter-proof shelters are normally combined in the same structure. This is generally accomplished by gas-proofing the bomb-protected shelter by stopping up extraneous air leaks and supplying the shelter with a gas-free air supply. This being the case, gas shelters will exist in the same variety of forms described in Chap. IV.

The two principal problems in providing gas shelters are: (1) the adaptation of existing buildings for this purpose; and (2) the gas-proofing of specially designed and constructed bomb-protected shelters.

The principal steps in *gas-proofing an existing building*, which has been adapted as a splinter-proof shelter, are (1) sealing up cracks and crevices through which gas may find entrance into the shelter; (2) providing an air lock or gas-proofing for doors that must be used as entrances to the shelter; (3) special treatment of windows to prevent entrance of gas into the shelter; and (4) providing means for furnishing an adequate supply of gas-free air to the shelter.

The following notes indicate various methods of sealing up extraneous openings in a gas shelter:

1. All cracks in *floors, walls, and ceilings* should be filled in with putty, wet paper pulp, or cotton waste or pasted over with strongly glued paper or adhesive tape. After filling cracks in the floor, sheets of paper should be pasted over the whole floor. Keyholes and other apertures should be carefully plugged.

2. The chimneys of *fireplaces* should be stuffed up with paper or rags to prevent draft and the front of the fireplace sealed with a sheet of plywood and adhesive tape.

3. Apertures around all *pipes to basins, sinks, etc.*, should be plugged up, as well as any similar opening through which air might enter the room.

4. All *trap doors*, skylights, and hatches in the room should be sealed, and all ventilators in the room or below the floor should be stopped up with rags or pasted over with strong paper.

It is important that every vent or grating in the building through which air might be drawn into the shelter should be blocked up. Typical structural defects that should be remedied in making a room in an ordinary building gas-tight are shown in Fig. 26.

All *doors* into a shelter, except those that must be used for entrance or emergency exit, should be permanently locked up and sealed around their edges, and the keyhole plugged, as indicated above. Doors that must be used should be provided with either an *air lock* or *gas curtain.*

An *air lock* is a compartment, in the passageway leading to the entrance of the shelter, with a door to the outside and a door to the shelter. By keeping one of these doors always closed when the other is open, the direct passage of air (and gas) from the outside into the shelter can be prevented. One of the most satisfactory methods of constructing an air lock is to set up two air *blanket doors*, about 6 to 9 ft. apart, across the entrance passageway, so that a person can enter the space between the blanket doors and adjust the fitting of the blankets before passing into the shelter. Each blanket is supported on an inclined frame, one end being attached to the top of the frame. Slats are nailed horizontally at intervals across the inside and outside of the blanket and weights are attached near its edges, to hold it in place when lowered and keep it pressed tightly against the frame. When

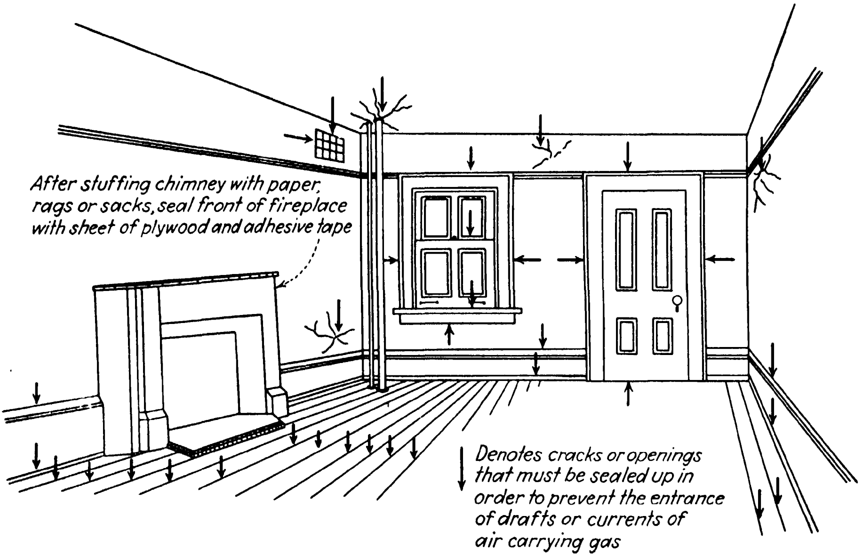

After stuffing chimney with paper, rags or sacks, seal front of fireplace with sheet of plywood and adhesive tape
↓ Denotes cracks or openings that must be sealed up in order to prevent the entrance of drafts or currents of air carrying gas

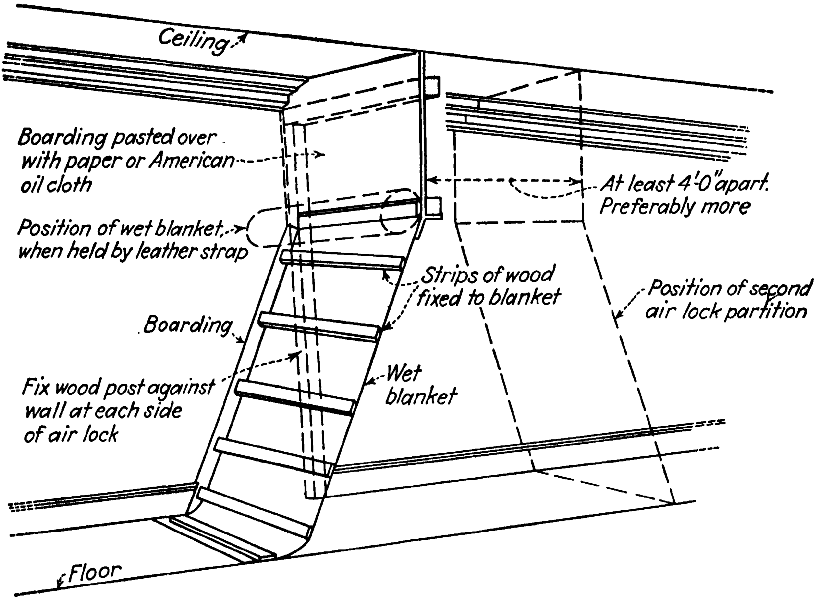
Fig. 26.—Preparation of gas-tight refuge room.

lowered into place, the two blanket doors make the shelter gasproof by forming an air lock between them (see Fig. 27).

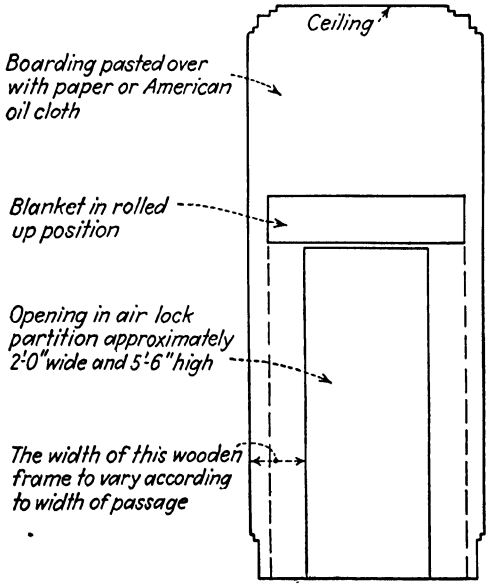
Where there is a door to the shelter, it can be made to serve in place of the inner blanket door by making it gas-tight. This can be done by nailing strips of rubber or felt around the edges of the door, so that it makes an airtight fit in its frame when closed. All keyholes and other cracks must, of course, be stopped up. Where there is no passageway outside the shelter, an air lock cannot be constructed and a more primitive form of gas protection, the *gas curtain*, must be substituted. A gas curtain is constructed by fastening a blanket with strips of wood on the outside of the door frame, except for some 5 ft. above the floor on the side away from the hinges. The bottom of the blanket is left loose at that corner, so that it can be lifted up to let a person through. About 1 ft. of the blanket is left trailing on the floor to prevent air drafts under it (see Fig. 28). If the blanket is impregnated with oil, it gives better protection.

In existing buildings that have been adapted, in whole or in part, as air raid shelters, *windows* that cannot be bricked up or otherwise permanently closed as described in Chap. IV, must be given special treatment. Since high explosive bombs may be used concurrently with gas and the blast of such bombs, bursting some distance from a window of ordinary glass, may shatter the glass and leave the window open to gas, it is essential that measures be taken to prevent this occurrence. Owing to the air pressure pulse produced by bomb blast, windows cannot be protected by fixing steel or wooden shutters of practicable thickness on the outside of the window frames. Experience has shown that despite such coverings, window glass is still shattered, by the pressure pulse transmitted through the covers. The most effective method of protecting a window against the blast effect of high explosive bombs is to construct outside of the window sandbag walls or earth traverses 2 ft. 6 in. thick which must entirely cover the window opening and abut the brickwork with an overlap of at least 1 ft. all around.

Where windows cannot be protected by barricades, it is necessary to reinforce or replace the ordinary glass in windows by some nonshattering transparent or translucent material, such as (1) celluloid, or cellulose acetate applied with cellulose varnish to the inner surface of the glass pane; (2) vitreocelloid material, such as


Ceiling
Boarding pasted over with paper or American oil cloth
At least 4'-0" apart. Preferably more
Position of wet blanket when held by leather strap
Strips of wood fixed to blanket
Position of second air lock partition
Boarding
Fix wood post against wall at each side of air lock
Wet blanket
Floor

SKETCH


Ceiling
Boarding pasted over with paper or American oil cloth
Blanket in rolled up position
Opening in air lock partition approximately 2'-0" wide and 5'-6" high
The width of this wooden frame to vary according to width of passage

ELEVATION

Fig. 27.—Air lock constructed with blanket screen.

"cellatoid," 0.1 in. thick reinforced by ½-in. wire mesh netting, substituted for the glass pane; (3) glass internally reinforced by wire netting, replacing ordinary glass panes; and (4) oil-impregnated gas-proof blankets nailed over windows on the inside.

An additional method of excluding gas when windows are perforated by blast or flying fragments is to attach to the inside of the window a flexible shutter, hinged at the top so that it will momentarily yield to the blast impulse but return to airtight position almost immediately. Such a shutter may be made of wallboard, plywood, or other resistant material fixed to a light wooden frame, accurately fitted to the window opening and having a rubber, felt, or thick cloth strip tacked around its contacting edges. The shutter should be held in place only by its friction with the window frame, so as not to offer resistance to the blast impulse but freely to swing inward and then return to its airtight position against the window frame.

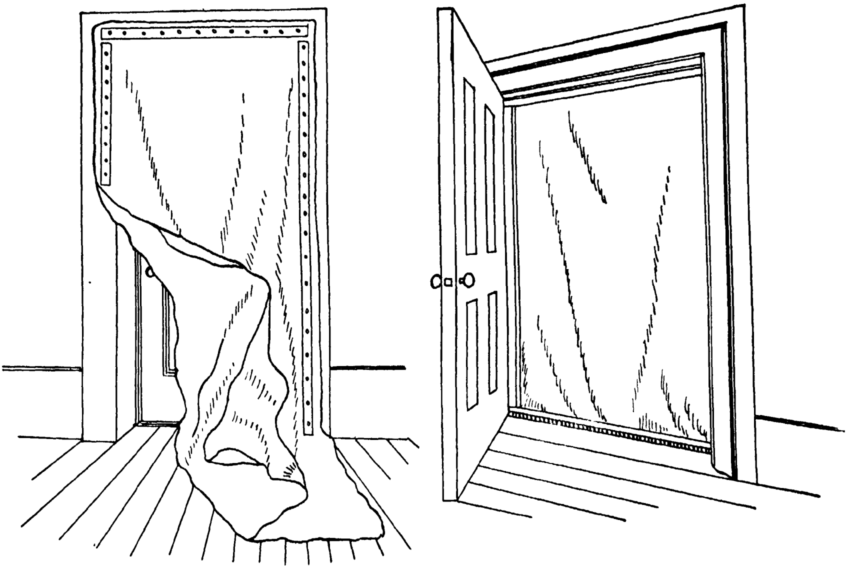


FIG. 28.—Gas-tight blanket door.

From the viewpoint of air supply, gas-proof shelters are of two kinds: (1) unventilated; and (2) ventilated. In *unventilated shelters* the air is rebreathed by the occupants and becomes progressively vitiated by exhaled carbon dioxide and water vapors. Accordingly, the length of time such a shelter can be occupied depends upon the size of the shelter, the number of occupants, and the temperature. For periods of occupation up to 3 hr. under normal summer conditions in the United States, an allowance of 100 sq. ft. of surface area (floor, ceiling, and walls), 180 cu. ft. of air space, and 6 sq. ft. of floor area per person is necessary, and the shelter capacity is determined by whichever rule gives the least number of persons.

The following figures indicate the maximum permissible number of occupants for *unventilated* shelters of the sizes indicated:

Inside dimensions of shelter, ft.	Maximum number of occupants	
	Up to 3 hr.	3 to 6 hr.
10 × 10 × 8 high	5	4
15 × 10 × 8 high	7	5
20 × 15 × 10 high	13	10
30 × 15 × 12 high	20	16
50 × 20 × 15 high	41	33

Under conditions of high temperature and humidity, the number of occupants must be reduced. Also, for periods of occupation exceeding 3 hr., discomfort due to foul air will gradually increase until the safe limit is reached at about 6 hr.

For *ventilated shelters*, fresh air may be drawn in from an intake point well above the ground where dangerous concentrations of gas are unlikely or through a chemical filter which purifies the air on the same principle as a gas-mask canister. In either case the air intake should be located so as to reduce, as far as practicable, the possibility of damage or destruction by high explosive bombs. By maintaining the air pressure in the gas shelter somewhat higher (3 to 5 mm. of water) than the outside atmosphere, the flow of air will always be from the inside out, the entrance of gas through extraneous cracks and openings being thus prevented.

In order to draw the required supply of air into the shelter and maintain a slight plenum, some sort of power-driven rotary fan is required. For shelters accommodating less than 25 persons, this fan may be manually operated by one person; for shelters accommodating up to 50 occupants, two men are required to operate the fan manually; for larger shelters, a motor-driven fan is required. As a rule the fan, chemical filter, and necessary valves and connections are built as assembled units, called *collective protectors,* which vary in size according to the number of occupants to be supplied with air (see Fig. 29).

The rate of air supply to a gas-tight shelter should be at least 150 cu. ft. of air per hour per person for periods of occupation up to 3 hr., and 450 cu. ft. per hour per person for periods beyond 3 hr. occupation. At these rates of air supply the occupant capacity of a ventilated shelter may be calculated as follows: At 150 cu. ft. of air per hour per person, divide the interior area of the shelter (ceiling, walls, and floor) by 40 if the shelter is aboveground and by 20 if the shelter is below ground. At 450 cu. ft. of air per hour per person, divide the interior area of a shelter aboveground by 30 for 3 hr. occupation and by 50 for 12 hr. occupation and for an underground shelter by 25 for 12 hr. occupation.

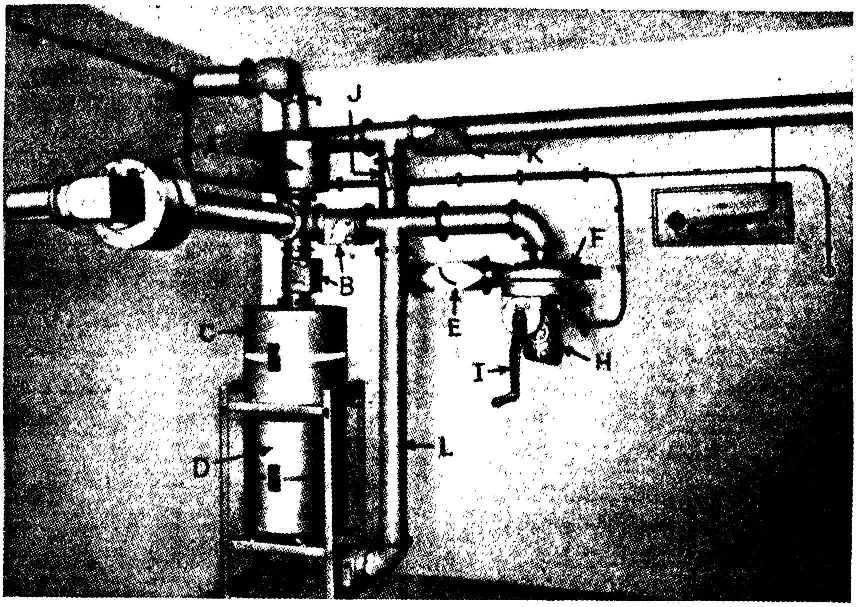


Fig. 29.—Collective protector (British commercial type) (Chema Mfg. Co., London).

A,A	Dust filters on air intake pipes
B	Control valve
C	Toxic smoke filter
D	Gas filter
E	Air flow meter
F	Rotary air pump
H	Electric motor for air pump
I	Hand crank for air pump
J	Control valve
K	Purified air outlet into refuge room
L	Purified air conduit

Thus, a shelter 10 by 10 by 10 ft. high, with a rate of ventilation of 150 cu. ft. per hour per person, can accommodate (1,000/40) 25 persons for 3 hr. if aboveground and, if below ground, (1,000/50) 20 persons for the same period. The same shelter, with a rate of ventilation of 450 cu. ft. per hour per person, can accommodate (1,000/30) 33 persons for 3 hr. and (1,000/50) 20 for 12 hr. if aboveground and, if below ground, (1,000/25) 40 persons for 12 hr.

If the air intake to a gas-proof shelter is damaged or destroyed during an air raid so as to cut off the air supply, it will be necessary to open a window or door and all occupants will have to put on gas masks and protective clothing until the damage can be repaired.

In deep underground dugouts, where there is no other access to air supply, in the event the air intake is cut off by bomb damage, it is advisable to provide an alternative means to take care of this contingency. This is usually accomplished by installing in the gas shelter an apparatus to purify and recirculate the air in the shelter. Such an apparatus is known as an "air regenerator" and consists of a device to remove excess carbon dioxide from the air (a CO_2 absorber) and a device for supplying additional oxygen from storage cylinders, at a measured rate of feed (an oxygen diffuser). When a gas shelter is equipped with an air regenerator of sufficient capacity, it may be occupied for as long as 48 hr. without an outside air supply.

Removal of Gas from Enclosed Spaces.—Despite the most careful preparation of gas shelters to ensure gas-tightness, a certain amount of gas may percolate into such shelters during heavy or prolonged attacks, particularly where the shelter is unventilated and persons enter or leave the shelter while gas is present outside. Accordingly, steps should be taken to clear the shelter of any accumulated gas as soon as the outside atmosphere is clear of gas. This is most effectively accomplished by opening all doors, windows, and gas curtains and creating a draft of air through the shelter. Any form of improvised fan, such as empty sandbags and ground sheets, will produce sufficient draft to clear an ordinary surface or semisurface shelter. In the deeper forms of underground shelter, a fire is the best means of clearing out the gas. The object of the fire is to heat the air which then rises and creates a draft by drawing the cooler air after it. If there are two or more exits, the fire should be placed near the one that causes the best draft. If only one exit is available, the fire should be placed at about one-third of the distance from the bottom of the exit. Gas shelters should be habitually left open during periods when no gas is present outside. If vesicant gas has accumulated in such quantity as to contaminate the interior of the shelter, decontamination should be effected as soon as the outside is clear of gas.

The same methods of clearing out gas apply to buildings. By opening all windows and doors and allowing the air to blow through the building the gas will soon be eliminated. Where a natural draft cannot thus be obtained, as possibly in the case of cellars, a fire should be built to create one. In case of severe accumulation of gas, floors and woodwork should be washed with a decontaminated agent. It is also advisable to remove furniture, etc., which smells of gas and air it in the sun and wind.

Marking and Clearing Contaminated Areas.—Where areas become contaminated during an air raid, they should be marked with suitable signs by Air Raid Wardens and police, as soon as practicable, and steps taken to clear out and exclude all members of the public who have no official ARP duties in such areas. Areas contaminated with vesicant gas should be avoided by routing all street traffic around the area on the upwind side. As to the down-wind distance at which an area contaminated with vesicant gas may be passed with reasonable safety, several factors must be considered, such as: the depth and width of the area, the gas concentration, temperature, wind velocity, and the time required to pass the area in the particular situation. Assuming no delay, it is probable that in most cases it will be reasonably safe to pass a vesicant contaminated area on the down-wind side at a distance equal to its depth.

Decontamination.—Personnel, material, and ground are contaminated by the adherence of toxic gases, in solid, liquid, or vapor form, as the result of exposure thereto. Decontamination is the process of freeing personnel, material, and ground from toxic gases by the destruction, removal, or sealing up of such gases. *Non-persistent* gases and toxic smokes are so rapidly dissipated by evaporation and air currents that it is unnecessary to provide any special decontamination means for removing these agents from personnel, material, and ground. For all such agents, nature is the best decontaminator; all that is required is ventilation and, for instruments and machinery, a simple cleaning and reoiling.

Persistent vesicant agents, such as mustard gas and lewisite, however, present a very different problem. Even small quantities of these gases are dangerous, and it is chiefly in connection with such gases that the problem of decontamination arises. Other than "weathering," the principal methods of decontamination are: (1) *destroying* the vesicant agents; (2) *sealing* them up with overlying materials; and (3) physically *removing* them to less dangerous places.

The action of weather on persistent gas is similar to that on water, in that the liquid is evaporated and may be partly hydrolyzed, while the vapor is blown away. The process is, of course, much slower in the case of persistent gas. Thus, if under any given conditions a certain quantity of water evaporates in 1 hr., the same quantity of liquid lewisite and mustard will evaporate in 10 and 38 hr., respectively, under the same conditions. Since weathering is a natural process and involves no labor, whereas the process of decontamination involves considerable labor, especially for ground and materials, the former method is preferred in dealing with contamination wherever practicable. The time required for weathering depends upon the degree of contamination, the meteorological conditions, and the nature of the ground or materials contaminated. The factors that accelerate weathering are wind, bright sunshine, high temperature, heavy rains, and exposed and impervious surfaces.

Vesicant gases may be *destroyed* by chemical neutralization, by boiling in water, or by burning.

The best all-round agent for chemically neutralizing vesicants is ordinary bleaching powder (chloride of lime). This material reacts vigorously with vesicants and changes them into physiologically inert compounds. The bleach may be applied in the form of powder mixed with dry earth or sand to prevent combustion, in the form of a paste, or as a liquid solution in water. The various appliances for decontaminating ground and materials are designed to apply bleach in either powder or liquid form to the contaminated surfaces (see Fig. 30).

Other agents for chemically neutralizing vesicants are: (1) free chlorine; (2) chlorine dissolved in carbon tetrachloride or kerosene; and (3) calcium hypochlorite, either in powder form or dissolved in water. All these chemicals destroy the molecules of vesicants and change them into harmless compounds.

When vesicant agents are brought in contact with boiling water, they are also destroyed by being split up into harmless components; hence, boiling contaminated articles, such as clothing, rubber boots, masks, and in general any material not injured by boiling, is one of the most effective methods of decontaminating such articles. Live steam acts in the same manner as boiling water and may be used to decontaminate articles that will not stand boiling.

Vesicant liquids and vapors are also chemically dissociated and destroyed in contact with flame, and hence contaminated ground and inflammable materials of little value can frequently be best decontaminated by burning. Where an area is burned over by setting fire to the vegetation or by igniting inflammable oils, poisonous fumes are given off in the initial stages and personnel should stand upwind or wear masks and protective clothing.

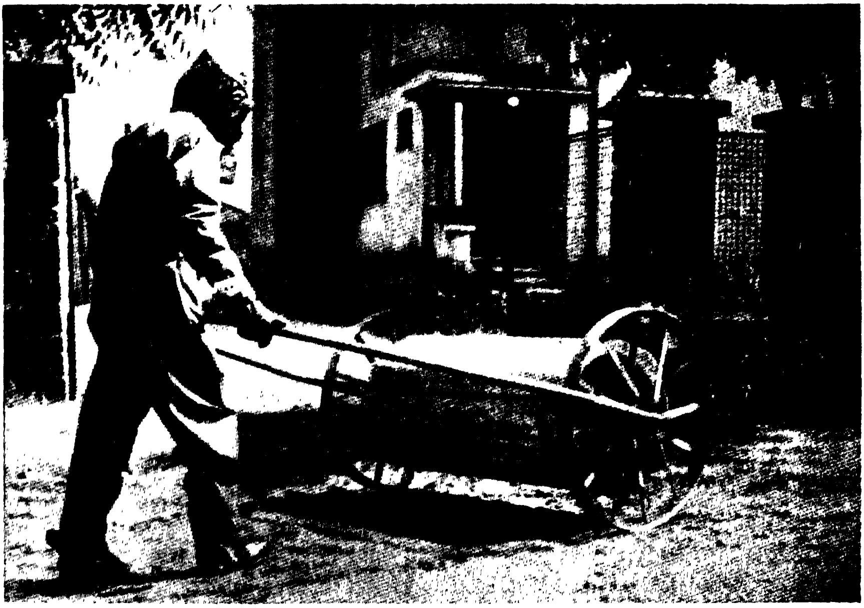


FIG. 30.—Mobile decontaminator (British commercial type) (Chema Mfg. Co., London).

The physical removal of vesicants is another method of decontamination and is most readily accomplished by swabbing with solvents and washing away with water. This method is purely mechanical and does not destroy the vesicant. It merely removes it to a place considered less dangerous, as, for example, the hosing of liquid mustard gas from a street into the gutters and sewers.

Vesicant liquids may be *removed* from surfaces of both personnel and material by swabbing with solvents, such as kerosene and carbon tetrachloride. The swabs must be burned after use. Hosing decontaminates surfaces by washing away vesicant liquids but must be done before they have penetrated into the material, usually within 30 min. after contamination. Then only about one-third of the vesicant is removed, and other methods of decontamination must be used to render the area safe.

Another method of decontamination, especially applicable to ground areas, is to *seal up* the vesicant liquid by covering it over and so preventing the vapor from escaping. A layer of 3 in. of earth or sand or 2 in. of a mixture of 3 parts of earth and 1 part of bleaching powder is required to seal up a liquid vesicant effectively. The liquid is, however, not destroyed and becomes active again if the seal is broken; hence, the area should be marked with suitable warning signs. Since about 1 ton of earth and bleach and considerable labor are required to seal 18 sq. yd. with a 2-in. layer, it is impracticable to seal extensive areas which should, therefore, be dealt with by other means.

Concrete and wooden surfaces can be sealed by applying a coat of water glass (sodium silicate) which forms a thin impervious surface. Bleach paste applied with a brush or spray is also effective for certain surfaces.

Clothing contaminated by vesicant vapors can be most easily *decontaminated* by weathering outdoors 24 hr. or until free from gas odor. Clothing contaminated by vesicant liquids should be boiled or steamed in laundry apparatus or other suitable receptacles.

Personnel can best be *decontaminated* by applying protective ointment, swabbing with solvents, and scrubbing with hot soap and water, as explained on pages 227 and 228.

The method of decontamination to be employed in any particular situation is largely a matter of judgment. Other methods of decontamination should never be employed where simple weathering will suffice or where the area can be closed.

Public Gas Cleansing Centers.—Gas cleansing centers are provided for the prompt treatment of *unwounded* persons who have become contaminated by vesicant liquids and vapors; wounded persons are treated in first aid stations even though they may be contaminated. Since contaminated persons must be speedily treated to prevent their becoming casualties, gas cleansing centers should be so located that they can be reached by all personnel to be served in 10 min. They comprise facilities where contaminated persons can undress, bathe, and reclothe themselves with safety and dispatch. As gas cleansing centers are designed to handle personnel in groups, they are a means of collective protection (see Chap. XIII).

In addition to public gas cleansing centers, as described above, it is also necessary to provide stations where ARP services personnel can be cleansed. Facilities for this purpose are generally included in central depots of the decontamination service. In general the cleansing facilities in these depots are similar to those in public gas cleansing centers, except that they are usually laid out on a smaller scale but are more elaborately equipped to deal with heavily contaminated cases (see Chap. XIII).

Anti-gas Precautions for Food and Water.—Though all war gases will, when brought in contact with food and water, contaminate them to some extent, the action of the tear and lung injurant gases is generally not serious and usually results only in imparting to the contaminated food and water a disagreeable taste or odor. Respiratory irritant gases (arsenical smokes) and vesicants, however, do produce a very serious poisoning effect upon food and water, the consumption of which may be fatal. On the other hand, an inexcusable wastage of foodstuffs will result if slightly contaminated supplies are unnecessarily destroyed through ignorance. It is, therefore, essential that the public in general, and those charged with the storage and handling of food and water supplies in particular, should clearly understand the effects of the various kinds of war gas upon food and water and under what conditions such contaminated supplies can be safely consumed.

The contamination of food by lung injurant gases, such as chlorine, phosgene, and chloropicrine, can generally be removed by ventilation and heating. A disagreeable taste usually remains, but such food can be safely consumed and should not be destroyed unless very heavily contaminated so that the odor of gas remains after ventilation and heating. Food contaminated with respiratory irritant gases (adamsite) and liquid vesicants (mustard gas and lewisite) is dangerous and must be destroyed. Most foodstuffs are not affected by vesicant vapors, except fatty foods, such as butter, cheese, and bacon, which become dangerous if exposed to high vapor concentrations. Other types of food are usually safe to eat after exposure to vesicant *vapor*.

Water contaminated by tear and lung injurant gases can generally be rendered potable by boiling until the odor of gas is removed. On the other hand, respiratory irritant and vesicant gases generally poison water, and it cannot be made suitable for use. A short exposure to weak concentrations of vesicant *vapor* does not usually render water dangerous to drink, but long exposure to strong concentrations may make the water dangerous. In no case should water exposed to vesicant vapors be drunk until tested.

The first principle in protecting food and water against gas, especially vesicants, is to keep it covered as tightly as possible. Food is fully protected by airtight bottles and hermetically sealed tin containers. Cartons of waxed cardboard, heavy cellophane, oilskin, and similar waterproof materials generally afford good protection. Greaseproof paper protects against vesicant vapor, but not adequately against the liquid. On the other hand, ordinary paper and cloth sacks and bags afford no protection against gas, and when they become contaminated the food should be destroyed. Foods that cannot be protected by gas-proof packages, such as fresh meats and vegetables, should be stored in gas-proofed storehouses. Also, places where food is prepared for consumption should be made gas-tight and should be closed during gas attacks. When wooden boxes and waxed cardboard or grease-proof paper cartons containing food have become contaminated, the food must be removed at once and may be safely consumed if the liquid vesicants have not had time to penetrate through the box.

Water storage tanks and basins should be covered by a roof, fitting as tightly as possible, so as to exclude any contaminated air from contacting the water. In the case of large city reservoirs that are impracticable to roof over, there is no feasible way to prevent contamination of the water by liquid vesicants. However, liquid mustard gas is heavier than water and sinks to the bottom where it slowly is hydrolyzed and destroyed. Where the water is drawn off carefully from the upper layers, the minute quantities of liquid mustard that might be present are readily removed by the ordinary process of water filtration. Water supplies from such reservoirs are therefore safe for use. If liquid mustard falls in small water tanks and shallow streams, the water will be sufficiently contaminated to be unsafe unless it is thoroughly boiled for ½ hr. before use. Chlorination without boiling is not sufficient.

Since lewisite contains arsenic, it renders all water, regardless of source, dangerous and, therefore, unsafe to use.

Anti-gas Organization.—To carry out the various activities concerning anti-gas protection mentioned in this chapter, a special organization is required. This organization forms a part of the ARPD and is principally concerned with the supply and issue of anti-gas equipment, the anti-gas training of Air Raid Wardens and other personnel involved in anti-gas protective measures, and with the general supervision of the execution of such measures in time of emergency. A further discussion of anti-gas organization for Civil Air Defense is contained in Chap. XIII.

CHAPTER VII

AIRCRAFT WARNING SERVICE*

General.—In order that the means of Active and Passive Air Defense may be brought into action against hostile air attack, in sufficient time to be effective, it is necessary that provision be made to detect the approach of enemy aircraft toward any part of the national frontier, to trace their flight over the invaded areas, and to give timely warning to the defense activities and inhabitants in such areas, before the arrival of the attacking planes. This is the function of the Aircraft Warning Service, and upon its efficient operation depends the success of the whole machinery of air defense.

Since the Aircraft Warning Service serves both the Active and Passive Air Defense, it is strictly speaking not an organic part of either organization. However, inasmuch as its primary mission is to warn the agencies of Active Defense, so that they may have time to get into action and oppose the threatened invasion, the Aircraft Warning Service is usually operated by the military as an adjunct to the Active Air Defense. At the same time, as the Aircraft Warning Service also serves to set in motion the whole machinery of Passive Air Defense, it is an essential prerequisite of that organization. For these reasons, the Aircraft Warning Service may be properly regarded as the connecting link between the Active and Passive Air Defense. Thus, although the Aircraft Warning Service is not a part of the Air Raid Precautions Department (ARPD), it performs an indispensable function in connection therewith and must accordingly be considered in formulating any Air Raid Precautions (ARP) scheme.

It is a part of the duty of the Aircraft Warning Service to transmit warning messages to one or more responsible agents of the ARPD in each community; thereafter, the responsibility for disseminating these warnings, within the boundaries of the community, devolves upon the local Director of Air Raid Precautions, acting through his agents duly appointed for this purpose. It is essential that this line of demarcation be kept clearly in mind by those charged with formulating schemes of Civil Air Defense.

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* The information contained in this chapter is based largely upon current European practice and might not necessarily be followed by the United States.

Organization.—The Aircraft Warning Service consists essentially in means for collecting and disseminating information concerning hostile aircraft approaching or crossing the national frontier, so that effective measures can be taken to protect the threatened areas from air raid or invasion.

The means of *collecting* information comprises generally a large number of observation posts for detecting the approach of hostile aircraft and means for speedily transmitting this information to certain designated "information centers," where it is collected and evaluated. This is generally known as the aircraft *Intelligence System.*

The means for *disseminating* information concerning invading hostile aircraft (outside of urban communities) comprises principally a central control station and a number of regional disseminating stations, all of which are in electrical communication with headquarters of active defense forces, the civil authorities of communities, and vital industrial establishments, in the defended area, so that warnings of imminent air attack may be speedily sent out to threatened areas. These disseminating means are collectively known as the aircraft *Warning System.*

The approach of hostile aircraft is usually detected by visual observation from the ground, with or without the aid of field glasses or other observing instruments; by audible perception from the ground, generally with the aid of sound locators; or by the use of scout and reconnaissance airplanes. Information concerning hostile aircraft may be transmitted from observers to information centers and thence to warning districts by means of telephone, telegraph, teletype, and radio communication. The telephone, being the quickest and most convenient means of communication, is the one most widely employed, and the other types of communication are generally utilized as supplementary means.

To facilitate the gathering and evaluating of information concerning hostile air activities, areas along the frontier to a depth of several hundred miles are divided into a number of operating sectors and zones with an information center in each. A sector may embrace several hundred miles of frontier and generally includes a number of zones, approximately 120 miles square, according to the size of the sector. Observation stations are established in each zone, with a minimum density of one station to each 8-mile square and are in telephone or radio communication with the zone information center. Each zone information center is also in communication (by telephone, telegraph, teletype, or radio) with its sector information center. The sector information centers are in turn in similar communication with each other and with the headquarters of the Aircraft Warning Service (see Fig. 31).

Each observation station transmits to its zone information center the following data on all hostile aircraft detected: (1) station code number; (2) number of hostile aircraft; (3) type of airplane (fighter, bomber, etc.); (4) time of discovery; (5) direction of flight; (6) location with reference to station (north, east, etc.); and (7) whether flying low, high, very high, etc. If the station has means for estimating the altitude of the hostile planes, these data are also included.

Each zone information center checks and plots on a large-scale map the position and direction of each hostile aircraft flight reported by observation posts and transmits these data to the sector information center, where it is combined with reports from other zone information centers in the sector.

Each zone and sector information center is also in electrical communication with: (1) all elements of the Active Defense; (2) the civil authorities of all communities; and (3) vital industrial establishments in their respective areas. Whenever it becomes apparent that a particular area or community is liable to imminent air attack, the sector or zone information center covering that area sends out the necessary warning messages to all concerned in the threatened locality.

To facilitate the dissemination of warning messages and also to restrict the warnings to the minimum threatened area, so as not to dislocate the normal life of the country needlessly, each zone is subdivided into a number of warning districts. These districts usually embrace an area about 60 miles square and have a message center for receiving and distributing warning messages.

As a rule, the sector information centers decide when and to which districts warning messages are to be sent out and send their warnings direct to the message center of each district to be warned. These message centers in turn send out warning messages to all

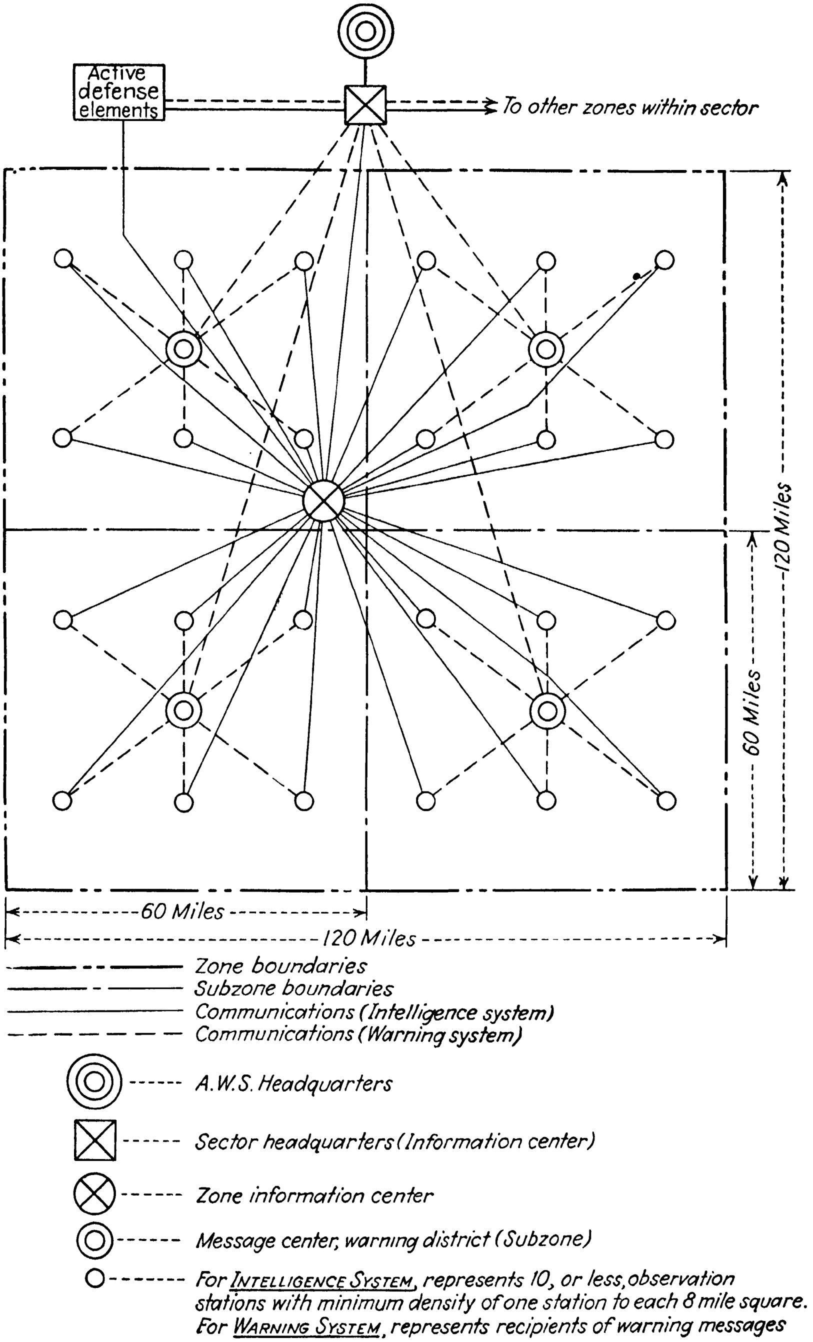
Active defense elements
To other zones within sector
120 Miles
60 Miles
60 Miles
120 Miles
Zone boundaries
Subzone boundaries
Communications (Intelligence system)
Communications (Warning system)
A.W.S. Headquarters
Sector headquarters (Information center)
Zone information center
Message center, warning district (Subzone)
For INTELLIGENCE SYSTEM, represents 10, or less, observation stations with minimum density of one station to each 8 mile square. For WARNING SYSTEM, represents recipients of warning messages

FIG. 31.—Diagram of Aircraft Warning Service (typical zone).

authorized recipients in each district. Occasionally, when surprise air attacks are delivered with such suddenness that there is not time to get the information from observers to the sector information center and thence to the warning districts, the zone information center may notify the message centers of warning districts direct and then report the matter to the sector information center.

Warning messages are dispatched from point of origin to the warning districts one at a time, as each becomes threatened by the progress of the air raid. Each message reaching a warning district is automatically distributed by telephone to all the recipients on a prearranged warning list. The warning district thus becomes the unit of the Warning System, and a whole district is warned, or not at all.

The warning districts generally comprise a group of three or four adjoining counties, so that the boundary of a district will coincide with local government boundaries. Occasionally, however, the telephone network of a particular area may be such that warning district boundaries cannot be made to coincide with county boundaries, and one county may thus be included in more than one warning district. This need not cause any difficulty if proper arrangements are made in advance.

The purpose of having clearly defined and comparatively small warning districts is to restrict the warning messages to the area that is actually threatened by a particular raid and thus to avoid spreading anxiety and dislocating normal activity more than is absolutely necessary. It follows, accordingly, that warning messages received in one warning district should not be repeated by a recipient to someone in another district. If the second district is in danger, it will be separately warned by the proper information center, and the passing of a warning message outside the district to which it applies will only spread unnecessary dislocation. A cardinal principle of the Aircraft Warning Service is to avoid unnecessary warnings and false alarms and at the same time to ensure that bombs are never dropped on a place that has not been warned.

So far as local authorities are concerned, the action with regard to the receipt of warning messages is confined to determining the appropriate methods of disseminating the warnings within the boundaries of the community. This includes the formulation of lists of authorized recipients (with their telephone numbers), for inclusion in the Municipal Warning List, and the installation and operation of a system of general area alarms and street signals. The detailed arrangements for the preparation of these local Warning Lists and their transmission to the local officials of the telephone service are usually the responsibility of the Chief Warden of the community, assisted by subordinate wardens and local police.

Equally important is the responsibility of the local authorities as to the areas within the city to be covered by public warning alarms and signals. As a general rule, the size of the Warning List will depend to some degree on the extent of the public warning signal system, and no recipients need be included in the List where they may be warned by the public signals alone.

Warning Messages.—Recent war experience in Europe has shown the need for four kinds of air raid warning message, as follows:

Preliminary Caution	Yellow*
Action Warning	Red*
Raiders Passed	Green*
Cancel Caution	White

The *Preliminary Caution* message is *confidential* and is issued by telephone only to a limited number of recipients who take unobtrusive measures to be ready to act instantly when the Action Warning is received, which may be from 5 to 10 min. later. The Caution message may also be issued to activities, such as blast furnaces and explosive factories, where action in connection with air raid precautions requires considerable time to put into effect.

The *Action Warning* message is issued by telephone to selected recipients, indicating that an air attack may occur within 5 to 10 min., and executive action with regard to air raid precautions should be taken. This is the message on which public alarm signals should be given.

The *Raiders Passed* message is issued by telephone to all recipients of the Action Warning message and means that the hostile raiders have left the area or that the threat of attack is no longer imminent. Public signals should be given on receipt of a Raiders Passed message, if one was given on the Warning message.

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* British official classification, *A.R.P. Memorandum* No. 8, "The Air Raid Warning System," p. 5, His Majesty's Stationery Office, London, 1938.

The *Cancel Caution* message is *confidential* and is issued by telephone to recipients of the Preliminary Caution. It means that the circumstances necessitating the issue of the Preliminary Caution or Action Warning messages are now passed.

The Preliminary Caution can be given only on a less definite forecast of the raiders' movements and must therefore be spread much more widely than an Action Warning for any given raid. Also, it will often not be followed by an Action Warning. For these reasons, the Preliminary Caution is a *confidential* message and is not intended to become known to the public. After the raiders have left a district, the Action Warning is canceled by a Raiders Passed message; and where the Action Warning has been communicated to the public by a public warning signal, a corresponding public signal should be given to indicate that the raiders have passed.

A *Raiders Passed* message is not to be confused with an *All Clear* signal to the public which means that the danger from the air raid no longer exists; for where persistent gas or time action high explosive bombs are used, the danger from an air raid may persist for some time after the raiders have passed. For this reason, the All Clear signal is not properly an Aircraft Warning Service message, but rather a local signal to be given by the local ARPD whenever its responsible officers consider the streets are safe for the public.

Public Warning Signals.—In large urban communities that are subject to air attack, the entire built-up area should be covered by public warning signal systems. All existing sirens, steam whistles, hooters, and power horns existing within the area to be covered should be earmarked for use as public warning signals in time of war and included in the Warning System for the community. A map of the community should be marked to show the locations of existing signals and the areas effectively covered by each. New instruments should then be spotted to fill in the gaps. Factory whistles and hooters, not included in the public signal system, should be sounded in time of war for passing on the public warning to the factory workers and supplementing the public signals. When so used for air raid warnings, they must not be used for other purposes.

Where areas cannot be covered by existing instruments, new instruments should, where possible, be located at existing plants and factories where steam or compressed air would be continuously available in time of war. At such places an effective steam or compressed air siren could be installed, and the remaining gaps covered by the use of self-generating sirens driven by electricity.

In extending the public signal system to vacant areas the minimum number of large instruments is preferred to a large number of small instruments, since the latter arrangement increases the number of recipients to which warning messages must be sent and the number of persons required to sound the instruments, as well as the number of instruments to be maintained in good working order.

Where not already available, provision should be made for a telephone connection to the point of operation of each public warning instrument. The proper spacing of new instruments depends upon how far such instruments can be heard under varying conditions. The vagaries of the travel of sound make it impossible to prescribe any fixed schedule of spacing, without actual trial on the ground. Tests recently conducted in London have shown that air raid warning signals can effectively cover an *average radius* of 1 mile. Hence it may be said that, subject to special local conditions, it appears that an area ought to be reasonably covered by a series of the loudest type of instrument spaced about 2 miles apart.

Types of Instrument.—Instruments suitable for air raid warning signals are of three general types:

1. Steam sirens and whistles.
2. Rotary compressed-air sirens, power driven.
3. Rotary self-generating sirens, electrically driven.

Steam sirens can be effectively operated by any steam pressure from 60 lb. /sq. in. up. For compressed-air sirens, a supply of compressed air is required to feed the siren, and in addition there must be power to turn the rotor. Where a supply of compressed air is assured, these sirens are most useful. Self-generating sirens merely require electric power for turning the rotor. These sirens are simple and efficient within their ranges.

Steam and compressed-air sirens are the loudest instruments; and where these sources of power are available, they are preferred to electrically driven instruments which may be cut off by air raid damage.

Regardless of what type of instrument is employed, it should be practically instantaneous in operation; it should give a note or range of notes of adequate loudness, within the frequency range of 400 to 800 cycles, and should be capable of operating intermittently or continuously with variable pitch; and it should be of a simple, rugged design not easily put out of order or liable to damage by weather.

Arrangements for the direct control of a group of public warning signals from a central point should be considered in all large communities. This arrangement reduces the number of persons required to operate the public signal system and has the advantage of unity of control. However, it requires special wiring which may be cut by air raid damage, unless placed in deep underground conduits. Even then, a large bomb striking directly over a conduit would put the system out of action, unless alternative arrangements were made to operate each signal independently upon receipt of a telephone warning message.

Public Warning Signal Codes. Whatever type of instrument is used for public warning signals, a standard code of signals should be adopted. This code should be simple, universal in application, and easily recognized by the man in the street.

The following public warning signals are prescribed in England:*
For the *Action Warning* message:

A signal of two minutes' duration consisting of

either

a fluctuating or "warbling" signal of varying pitch in which the frequency range is not less than 10 per cent above and below the mean pitch, the complete cycle of each fluctuation to extend over a period of 3 to 8 seconds,

or

a succession of intermittent blasts of about 5 seconds duration separated by a silent period of about 3 seconds.

For the Raiders Passed message:

A continuous signal of two minutes duration at a steady pitch.

Since the Preliminary Caution and Cancel Caution messages are not publicly disseminated, no special code signals are required for them.

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* *Ibid.*, p. 169.

Local Gas Signals.—Since it is naturally impossible to tell when or where gas may be dropped, any gas warning must be given by someone on the spot, after the presence of gas has been detected. The duty of sounding local gas warnings is, therefore, generally delegated to the Air Raid Wardens and police. A distinctive signal is required, and the instrument selected for this purpose in England is the police rattle. The instrument used in England to mark the end of gas danger in a sector in which rattles have been sounded is the ordinary hand bell which is rung by the same Wardens. The British system of street signals is as follows:*

1. Sharp blasts of whistles mean reinforcement or repetition of the Action Warning Signal.
2. Hand rattles mean local gas warning.
3. Hand bells mean, either cancellation of local gas warning (all clear), or (if there has been no such warning) reinforcement or repetition of "Raiders Passed" signal.

Warning Signals in Rural Areas.—In rural areas where the population is more scattered, a complete system of public signals is neither practicable nor necessary. In such areas the information that raiders are in the vicinity may be conveyed by telephone to an authorized recipient in the village or township (*e.g.*, the Air Raid Warden or constable); he will then warn those directly concerned by any means locally available, such as the village school bell, two or three shots with a shotgun, or even a small hand-operated siren. Factories in isolated locations should arrange their signals to warn not only the workers in the plant, but also those who live in the neighborhood of the premises.

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* *Ibid.*, p. 169.

CHAPTER VIII

AIR RAID WARDEN SERVICE*

General.—An Air Raid Warden is a responsible citizen of the community chosen to be a leader and adviser of his neighbors in a small area, in which he is known and respected. He will not normally be used outside the immediate neighborhood of his home or place of business. Within his area, or "sector," he is needed to perform a number of important duties in case of an attack and assists the civil authorities in safeguarding the general public. Though a Warden is a volunteer worker and his services are unpaid, he forms a definite and important part of every local air raid precautions (ARP) organization. He is appointed by the mayor of the city or other local authority and is furnished with an official letter or card of appointment, as a credential of his position and authority. After completion of his training, he wears a distinctive badge and arm band as evidence of his office.

In most European countries, Air Raid Wardens are clothed with limited police power to enable them to enforce the ARP orders and regulations which they are charged with executing. In some countries, notably England, Wardens do not have any police power but depend upon their neighbors voluntarily to carry out their orders and instructions because of the confidence felt in them. In case of need, they may call upon policemen and special constables in the neighborhood to assist them in enforcing public obedience to the regulations and orders of the local authorities.

The question as to whether or not Air Raid Wardens should be clothed with police power in order properly to perform their duties is one that depends largely upon local conditions. Wherever it is found desirable to do so, they may be given police power by swearing them in as special police or deputy constables. In no case, however, should Wardens have authority to assume command of first aid parties, fire patrols, decontamination squads, or other personnel of the several ARP services. Their duties will be to guide these other agencies to the places where their services are needed, to show them where telephone and local facilities are available, and generally to assist them as much as possible.

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* The information contained in this chapter is based largely upon present British practice and might not necessarily be followed by the United States.

Duties of Wardens.—In time of peace the principal duties of an Air Raid Warden are:

1. To make a thorough study of the area assigned as his duty sector, in order to become well acquainted with its vulnerable spots, its air raid shelters, its communications, and in general, with its ARP installations and features.
2. To make himself personally known to all the residents in his sector and see that they are generally acquainted with such of the plans and regulations of the Air Raid Precautions Department (ARPD) as apply to that area.
3. To advise the inhabitants of his sector how to prepare precautions in their own homes.
4. To prepare a plan for distributing gas masks and other protective equipment to residents of his sector and, when so authorized, to issue and supervise the fitting of masks to individuals.
5. To act, generally, as the channel of communication between the local authority and residents of his sector in any ARP matters.

In time of *war*, the duties of Air Raid Wardens comprise the following:

1. To aid and advise their neighbors what to do in case of an attack and see that they are provided with gas masks.
2. Promptly to spread air raid alarms in their sectors when Action Warning messages are received; to detect and warn the public of the presence of gas; and to spread the Raiders Passed and All Clear signals to indicate when the danger of gas has ceased.
3. To guide members of the public to shelter when an air raid warning is received and see that order and discipline are maintained in public shelters during air raids.
4. To assist in dealing with casualties or bomb damage until skilled help arrives.
5. To report the fall of bombs in any part of the district and the extent of the damage caused and to summon aid as required.
6. Constantly to be on the lookout for fires and report them promptly to the fire department.
7. To help householders and fire patrols to fight incipient fires, until the firemen arrive.

8. To assist occupants of buildings that have been damaged by bombs to find new shelter.

9. To guide the police, firemen, first aid parties, rescue parties, etc., on arrival, to the scene of damage and to convey messages and render assistance to police and firemen.

10. To prevent panic and maintain morale by setting an example.

From what has been said above, it will be appreciated that Air Raid Wardens are the heart of the ARPD, for upon them falls the burden of seeing that the public knows how to utilize the various facilities offered by the ARP services for the protection of the civil population and that the citizenry obeys the many regulations and decrees made by the local authorities to promote the public safety in time of emergency.

Organization.—As in the case of the Fire Precautions Service, the Air Raid Warden Service may be organized either as a part of the permanent city police department or as a separate service, functioning under the Director of the ARPD. There are advantages and disadvantages attached to either scheme or organization. On the one hand, the functions of Air Raid Wardens are closely allied to those of the police, and the public soon comes to look to them for responsible help and guidance in the same way that it looks to the police. Also, in time of war, Wardens are even more closely associated with the police in maintaining public order, and in many countries, they have the status of special police. For these reasons, it is advantageous to organize them as a special branch of the regular police department. In this case, the head of the Warden Service is one of the Assistant Chiefs of the Metropolitan Police Department, who reports direct to the Chief of Police, and supervises the Warden Service.

On the other hand, the Wardens have many duties not connected with police functions but work in close collaboration with other ARP services, such as the First Aid, Rescue, Fire, and Decontamination Services. Moreover, the duties devolving upon the police in time of peace are very substantial and are greatly increased in time of war, and the additional work of controlling the Warden Service would usually be more than the ordinary administrative organization of the police department could handle. For these reasons, Air Raid Wardens should be organized as a separate corps, distinct from the regular police force, and included under the

ARPD. In this case, the head of the Wardens is known as the Chief of Air Raid Warden Service, and he reports to the Director of the ARPD.

The balance of convenience, between the two schemes of organization, hinges mainly upon the size of the community. For smaller cities (under 100,000 population), the advantage appears to be in favor of the scheme of incorporating the Warden Service into the regular police department, as this can generally be done in such communities without overburdening the Chief of Police and producing an unwieldy organization. On the other hand, in the larger cities (over 500,000 population), the case is just the opposite, and better results can be obtained by divorcing the Wardens from the police force and organizing them as a separate service under the Director of the ARPD. For cities of intermediate size (between 100,000 and 500,000), either scheme of organization may be employed, depending upon local conditions in each case.

Regardless of which scheme of organization is adopted for any particular community, the Wardens and regular police must work in the closest association, especially in time of emergency, and the same is true with respect to the Wardens and workers of the other ARP services.

Wardens' Districts and Posts.—The unit of organization of the Warden Service is the *sector*, comprising a resident population varying from a maximum of 1,000, in the most congested parts of a city, to a minimum of 500 in outlying residential sections. We shall consider first the sectors in congested areas.

In the large American cities (over 500,000) the population (1940) varies from a maximum of about 25,000 per square mile (New York, N.Y.) to a minimum of about 11,000 (Washington, D.C.), the average for the metropolitan areas of these cities being 14,600. The density of population *within these cities* varies still more widely, being as high as 90,000 per square mile in the most congested parts of the largest city to as low as 20,000 for the smaller cities in this group. The *average* population of the most densely populated areas of the largest cities is approximately 35,000 per square mile (56 per acre)..

The size of city blocks also varies considerably in American cities, the average being about 12 blocks to the lineal mile, or 144 blocks to the square mile. With an average population of 36,000 per square mile, each city block in a congested area would contain

250 residents. Four such blocks, having a resident population of 1,000, would constitute an Air Raid Warden's sector and would cover a square area of ⅙ mile on a side. Under such conditions, one *Warden's post* is allotted for each four adjoining sectors and is placed as nearly as possible in the center of the square constituting the four sectors, which is known as a *district.*

In congested areas, then, a *Warden's post* is established in each *district,* which has a resident population of 4,000 and covers a square area ⅓ mile on a side (see Fig. 32). Each such post is manned by the following personnel:

For 1 shift:		
	1	Warden
	3	Associate Wardens
	16	Assistant Wardens
Total.	20	

This organization allows one Warden (or Associate) to each sector and one Assistant Warden for each city block. Normally the Warden, or his Senior Associate, remains at the Warden's post at all times, while the other Associates supervise work of the Assistants in the district. Each Warden and Associate Warden is a resident of a different sector in the district and each supervises the Wardens' work in his sector. Two shifts, totaling 40 men, are required to man each district on a 24-hr. basis, although they are on active duty only during air raid alarms. On the basis of 40 Wardens per district, 1 Warden per 100 population must be enrolled for active duty, with an additional 25 per cent in reserve to provide for sickness, casualties, and unforeseen contingencies.

In unusually congested areas where there are many large apartments and tenements, each housing over 100 occupants, it is desirable to have a *special Warden* for each such building, chosen from those living or working on the premises. These Wardens should normally be regarded as part of the public Warden Service, and should be appointed and trained by the Air Raid Warden Service. Where several special Wardens are resident in a sector, they may assist the sector Wardens; and, in such cases, the sectors could contain more than 1,000 residents.

Likewise, where business and industrial premises contain more than 100 employees each, the owners are expected to organize factory or office guards for Warden duty within the premises. Such guards should not form part of the public Warden Service, but the same people may be enrolled as public Wardens for duty outside their regular working hours in their neighborhoods.

As the residential and outlying sections of a city are much less densely populated than the congested portions, districts containing 1,000 inhabitants will be much larger in such outlying areas than in the congested localities. In such cases, a Warden's post can serve only one or two sectors, the limiting factor being that in no case should any part of the area served by a post be more than ⅔ mile (10 min. walk) from the post by the shortest route available for a Warden to proceed on foot. As a rule, this limitation will result in

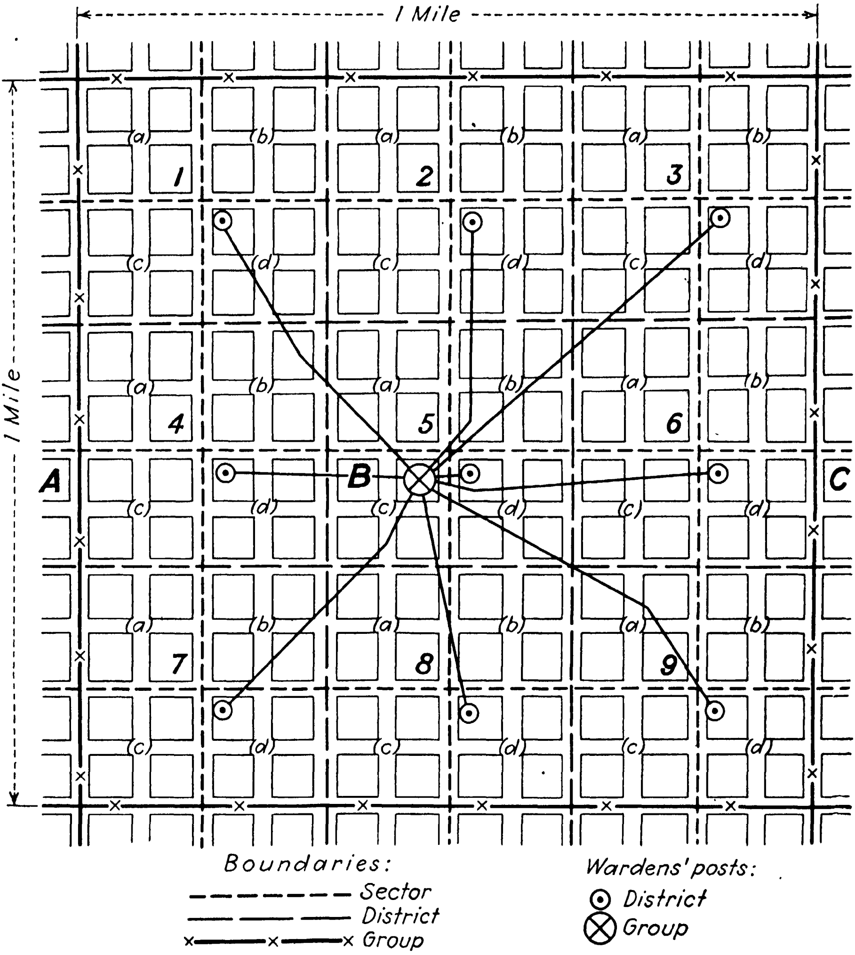

FIG. 32.—Diagram of Warden districts.

sectors containing 1,000 residents being about twice the area of a sector in a congested section of the city.

In residential areas, therefore, one Warden's post is normally allotted to each two sectors and serves a population of 2,000. Such posts will require only 10 men to a shift, organized as follows:

1 Warden.
1 Associate Warden.
8 Assistant Wardens.

This organization allows one Warden (or Associate) to each sector and one Assistant Warden for each two city blocks.

Higher Organization.—Each nine adjoining Districts are organized into a *Group* which, in congested localities, covers an average area of 1 square mile and contains an average population of 36,000. Each group is allotted a Senior Warden's post established as a headquarters near the center of the area.

For cities between 36,000 and 108,000 population, the Groups are organized into *Divisions*, with a maximum of three groups to a division. Each Division is supervised by a Principal Warden, who has a deputy, and operates from a Principal Warden's post near the center of the division area.

Similarly, for cities of 100,000 to 300,000, the Divisions are grouped into a *Department*, with a maximum of three divisions to a department. Each Department is supervised by a Head Warden, who has a deputy and operates from a Head Warden's post near the center of the department area (see Fig. 33).

In cities of 300,000 to 1,000,000, the Departments are grouped into a *Zone*, with a maximum of three departments to a zone. Each Zone is supervised by a Chief Warden, who has one or more deputies and operates from a Chief Warden's post near the center of the zone. If the city is between 1,000,000 and 2,000,000, it would be divided into two zones, of two departments each (total population 1,333,000) or two zones, one with three departments and the other with two (total population 1,667,000). For cities over 2,000,000, the metropolitan area is divided into zones of approximately 1,000,000 population each. Thus, New York City, with a population of 7,000,000, would be organized into seven zones, each having three departments and containing 1,000,000 residents each (Fig. 33).

The Warden Service of a large city (over 1,000,000) is supervised by the Chief of Air Raid Warden Service, who is assisted by several deputies and a technical and administrative staff. He operates from a general headquarters near the center of the city and is responsible for the organization, equipment, training, and operation of the Air Raid Warden Service of the city.

The tabulation at the top of page 182 shows the Warden System for large cities, as described above, in summary form.

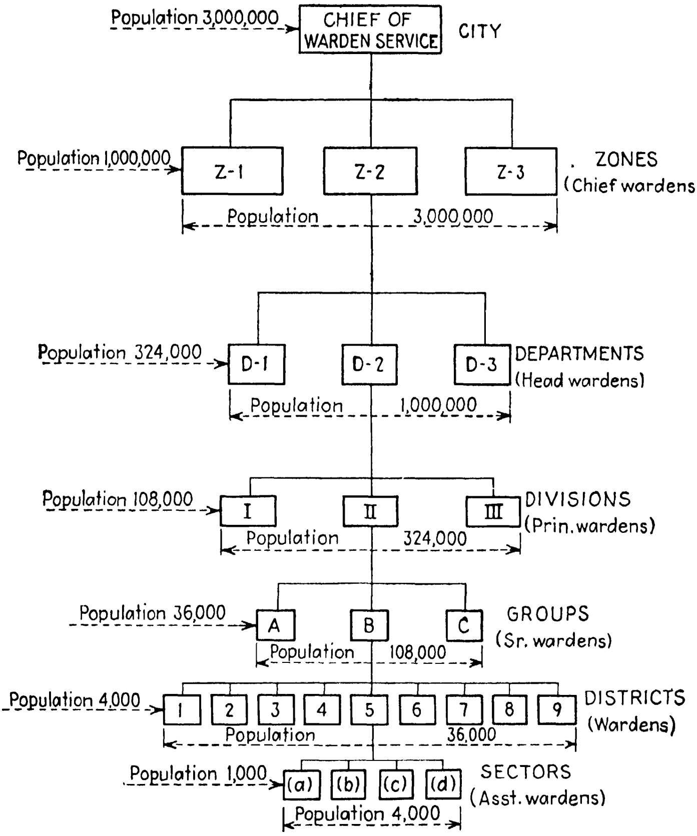

FIG. 33.—Diagram of Warden organization.

If the population of the city does not exceed 1,000,000, then the Chief Wardens' zones are unnecessary, and the Head Wardens report direct to the Chief of the Warden Service; if not over 33,000 population, Head Wardens' departments are eliminated, and the Principal Wardens report direct to the Chief of the Warden Service; etc.

Location of Wardens' Posts.—Having determined the number and location of subdivisions and Wardens' posts, on the principles

Unit of city*	Average area	Average population	Official	Jurisdiction comprises
Block	1/12 mile square	250	Assistant Warden	1 block
Sector	1/6 mile square	1,000	Associate Warden	4 blocks
District	1/3 mile square	4,000	Warden	4 sectors
Group	1 mile square	36,000	Senior Warden	9 districts
Division	3 square miles	108,000	Principal Warden	3 groups
Department	9 square miles	324,000	Head Warden	3 divisions
Zone	27 square miles	972,000	Chief Warden	3 departments
Whole city†	81 square miles	2,916,000	Chief of Warden Service	3 zones

* ARPD classification..

† About 3,000,000 population.

indicated above, the local authorities then proceed to select the premises to be used for the latter. A school, a hall, the basement of a public library, or a garage usually affords the best location for a Warden's post. In some cases, however, it may be more convenient to use the house, store, or shop of one of the Wardens, if he is willing. It is important that a Warden's post be located near the center of the area it serves; this is particularly true of district Wardens' posts, since no built-up part of the district should be more than ½ mile from a post by the shortest route on foot. As soon as the premises for a post are selected, it should be made ready for immediate occupation in an emergency. All Wardens' posts from the lowest to the highest echelons should have at least two telephones installed, ready for use.

Identification of Areas and Posts.—For purposes of identification, a standard system of nomenclature is used to denote each area and element in the Warden System, as follows:

Area	Symbol	Warden's post designation
Zone	Z1, Z2, etc.	Post Z1, etc.
Department	D3, D6, etc.	Post D6, etc.
Division	I, V, XVI, etc.	Post V, etc.
Group	A, B, C, etc.	Post IB, VC, etc.
District	1, 2, 3, etc.	Post IA2, IIIB8, etc.
Sector	(*a*) (*b*) (*c*), etc.	Sector designation IA2 (*b*), etc.
City block	(1) (2) (3), etc.	Block designation IA2 (*b*) (2), etc.

(See Fig. 33.)

Paid Assistants.—Though Wardens of all grades are unpaid volunteer workers, each Senior and higher grade Warden should be assisted by a paid executive officer whose principal duties are to take charge of the administration, training, and organization of the Wardens in the jurisdiction. These executive officers should have such clerical assistance as they need to conduct correspondence, render reports, maintain proper records, etc.

Each Senior and higher Warden should supervise, within his area, the recruitment, equipment, and training of Wardens and be responsible for assigning them to posts and other duties, arranging rotations of duty, replacement in case of sickness and injury, etc. These Wardens, however, are not a channel of communication in time of air raids. On the contrary, each individual district Warden sends his routine damage reports direct in accordance with the prescribed system of reporting, and not through the Senior and higher Wardens (see Chap. XIV).

Wardens in Rural Areas.—In rural areas subject to air attack, Wardens are normally allotted on the basis of about 3 per 500 population. As a rule, their districts will include the whole village or township; but where the area is so large as to extend beyond ½ mile from the Warden's post, it should be subdivided into sectors, with subposts established in each sector. One Warden's post per district is sufficient. It should be located near the center of the district and used as a rallying point for ARP volunteers generally. The sector subpost, if any, can usually be the home or place of business of the resident Assistant Warden. As rural areas will seldom, if ever, be subjected to intense or prolonged air attacks, one relief of Wardens is sufficient to man the post in such districts.

Training of Wardens.—The training of Air Raid Wardens should be conducted on progressive lines, following a logical sequence of subjects, in two distinct phases: individual and collective.

Individual training should be as practical as possible and should include the following subjects:

1. Important facts about his duty area.
2. The local ARP organization.
3. Relations with public and police.
4. Protection of homes against air raids.
5. Knowledge of the air raid warning system and the various types and kinds of warning.
6. Anti-gas precautions, the fitting and distribution of masks to the public, and the detection of gases.

7. Reporting of bomb falls and damage, message writing, and use of maps.
8. Elementary methods of protection against high explosive bombs, including knowledge of location and capacity of local public shelters.
9. Methods of dealing with incendiary bombs and fighting incipient fires.
10. Knowledge of Fire Precautions Service organization.
11. Elementary first aid.
12. Reporting on bomb damage of water and gas mains, sewers, and electric conduits.
13. Equipment of Wardens' posts and its uses.

This training is generally given at a central ARP training school in each community (see Chap. XV).

Upon the satisfactory completion of the foregoing individual training, Wardens should be grouped as nearly as possible to conform to their actual duty posts and given the following *collective training*, by Senior Wardens, under the general direction of higher Wardens:

1. The operation of a post:
   - *a.* Duties in peace and war.
   - *b.* Distribution and fitting of masks.
   - *c.* Manning a post in an emergency.
   - *d.* Patrols.
   - *e.* Action on air raid warnings.
2. Reporting:
   - *a.* Use of authorized message forms.
   - *b.* Practice in telephoning and writing messages.
   - *c.* Intercommunications when an incident occurs.
   - *d.* Alternative methods of reporting when normal channels fail.
3. Incidents:
   - *a.* Action on the fall of high explosive and incendiary bombs.
   - *b.* Action in the presence of gas.
   - *c.* Action in case of panic.
   - *d.* Dealing with casualties.
   - *e.* Guiding and assisting rescue, first aid, auxiliary fire, and other parties.
4. Action after a raid:
   - *a.* Responsibilities and duties on signals for Raiders Passed and All Clear.

b. Reconnaissance of sector or area to ascertain any further action required.
c. Control of general public.
d. Reporting All Clear when area is safe from gas.
e. Removal and temporary accommodation of homeless persons.

Equipment of Wardens' Posts.—Each Warden's post should be supplied with the following equipment:

1. 1 journal book for recording events and activities.
2. 3 large flashlights.
3. 3 whistles.
4. 2 hand rattles and 1 hand bell (gas alarms).
5. Small first aid kit.
6. A complete anti-gas suit and mask, steel helmet, and distinctive arm band, for each Warden.

Gas Mask Depot.—In each Warden's district, there should be located a distributing depot for civilian gas masks and special masks and protective clothing for members of the ARPD. Until such time as hostilities appear imminent, gas masks should be stored in the depots in sufficient quantity to equip the civil population and ARP personnel in that area. When authorized by higher authority the civilian masks are issued to the people in the district by the Warden in charge of the district post. Masks and protective clothing are issued to ARP personnel as required for their training and duty.

LIGHTING RESTRICTIONS AND BLACKOUTS

General.—Ground lights are a material aid to the navigation of aircraft at night, for they serve to guide pilots to a particular objective or help them to determine their position. Accordingly, in time of war, it is necessary to impose drastic lighting restrictions upon important communities and areas subject to air attack, to the end that no lights will be visible to aid hostile aircraft in carrying out night attacks on such objectives.

Effectively to blackout a community requires a well-worked-out plan of lighting restriction, backed up by a strong enforcement order by competent authority, and the wholehearted cooperation of all the residents of the community. An executive order for lighting restrictions and blackouts should be issued at the outbreak of war by the Chief of State, as emergency legislation. This order will impose general darkening of certain areas and communities as a permanent condition for the duration of the emergency and will specify the requirements of lighting at night, with which all concerned must comply. The prescribed restrictions deal generally with the different classes of lighting indicated below and are enforced by the Air Raid Wardens and police.

Although the restriction of lighting generally is not a function of the Air Raid Warden Service, the Wardens are more closely connected with this matter than any other agency of the ARPD, both from the standpoint of advice to the public and enforcement of the regulations. For this reason, the subject is included in this chapter.

External Lights.—All external lights should be forbidden. Hence, during hours of darkness, all lights on the outside of buildings, illuminated advertisements and signs, street lights, etc., should be extinguished. Factories and industrial premises carrying on processes emitting glare should take steps to screen or otherwise effectively conceal the same.

In the case of processes carried on in open or semiopen plants, such as blast furnaces and steel mills, a certain amount of glare visible after dark is unavoidable. As such industries are generally vital to the national defense, they are usually exempted from compliance with the regulations against exposed glares, provided that arrangements are made rapidly to conceal the glare upon receipt of an air raid warning. For blast furnaces, the most effective method of temporarily concealing glare during an air raid is to blanket the plant area with a thick smoke screen. This can be done by installing a series of large chemical smoke generators in a ring around the plant area and setting off those on the windward sign when an air attack is imminent.

Internal Lighting.—All indoor lights should be restricted to the minimum necessary to carry on normal activities within the building; and steps should be taken, in the case of all homes and business premises, to mask all windows, doors, and skylights, so that no light is visible from the outside.

Windows can be masked by opaque blinds or curtains which may consist of dark-blue or green glazed Holland, rubberized cloth, or thick black or brown paper. Blinds should overlap the whole window opening and should be mounted on rollers or secured in guides or by cords, so that they will not be displaced by wind when the window is open or broken. It is important that no light should show around the edges of the blinds; this can be accomplished by painting the edges of the window with opaque paint.

Where the light from a window may be dispensed with, the window may be made lightproof by closing it with a screen made of timber, tin plate, plywood, corrugated paper, etc. Alternatively, the glass may be coated with a dark opaque paint, provided that blankets or tarpaulins are kept in reserve as temporary covers to prevent exposure of light if the glass is broken.

It is often impracticable to arrange lightproof blinds for skylights and other horizontal glass surfaces. In some cases, movable screens independently supported are a satisfactory means of preventing the escape of light through skylights. In other cases, internally fixed tarpaulins or externally constructed movable screens may solve the problem.

To prevent the escape of light through *open doors*, a heavy, internally hung curtain may be used or a vestibule with double doors, so that one could always be closed while the other is open. An anti-gas air lock, as described in Chap. VI, also makes a satisfactory lightproof door.

Shading of Indoor Lights.—Since lightproof windows, skylights, and doors may be shattered by high explosive bombs, it is important that all indoor lights in homes and business premises be shaded so as to prevent direct light from being cast above the horizontal and to confine it to the smallest area required to be lighted. In addition, all lights should be connected to a single switch, so that they can be instantly extinguished in the event of damage causing exposure of lighting.

Traffic Lighting.—Road vehicles, streetcars, and railroad trains should be allowed to use head lamps provided that they are heavily screened and dimmed, so as to be invisible from the air. Interior lighting in all road and rail vehicles should be dimmed and screened so as not to be visible from outside. Shipping, navigation, and aircraft lights should be similarly restricted as prescribed in detail by the controlling authorities.

Aids to Traffic Movement.—Adequate means for aiding movement of vehicles should be required in all streets likely to carry a considerable volume of traffic. Such aids to traffic movement under blackout conditions comprise the following:

1. Screened traffic signals.
2. Warning and direction signs.

3. Painting on street curbs, trees, posts, and pavements.
4. Lighting of obstructions.

Traffic signal lights are kept in operation but are masked by opaque paint, leaving an opening for the emission of light in the form of a Maltese cross, 3 in. long by ⅛ in. wide.

Traffic signs, such as "One Way Only" and "No Left Turn," route numbers, and advance direction signs are also kept in operation; but they are screened from above and are so dimmed as to be legible, *under blackout conditions,* at a distance of 100 ft. horizontally but are not noticeable a few hundred feet above the street.

White or *luminous paint* and dim, well-screened *indicator lights* are used to mark curbs, trees, and posts that flank streets and roadways and also to indicate the line of the road, obstructions, and danger points.

Obstructions on all streets and roadways, such as safety islands, trees, etc., must be indicated by dimmed and well-screened lights that are not noticeable a few hundred feet above the street.

Lighting restrictions and blackouts are an important feature of precautionary measures against air attack, and they are effective only to the extent that the public wholeheartedly cooperates with the authorities in following the regulations and the Air Raid Wardens and police are vigilant in seeing that violations of the regulations are promptly corrected.

CHAPTER IX

FIRST AID AND MEDICAL SERVICE

General.—Since air raids on urban communities are likely to produce a large number of casualties among the civil population, it is necessary to provide means for their prompt collection, first aid treatment, and admission to hospitals where required. It will also be necessary to provide additional hospital facilities for such casualties, as well as means for medically treating persons who have been contaminated with gas but do not require hospitalization. To carry out these functions a First Aid and Medical Service should be organized in each urban community subject to air attack. The extent and elaboration of this Service will depend upon the size of the community and the first aid and hospital facilities already existing. A well-organized and efficient First Aid and Medical Service is an important factor in maintaining the morale of the population.

As it is impossible to forecast the number of casualties that will require treatment in any particular locality, the provision for dealing with casualties and contaminated persons should be governed primarily by considerations of area. In general, first aid posts should be located at frequent intervals, so that their parties can quickly reach the scene of damage and no casualty will have to travel far to receive aid. The scale of hospital accommodation required will depend upon the density of the population and the existing hospital facilities. The personnel required to man the various instrumentalities of the First Aid and Medical Service should be based upon a minimum of about 350 members per 100,000 population, exclusive of hospital staffs. Provision should also be made for additional trained personnel in reserve beyond those required for the initial operation of the service.

Air raid casualties may be due to wounds, gas, or shock. They may be of either sex and any age and may or may not be also contaminated with persistent gas. In order to facilitate the handling of these casualties, it is desirable to classify them into three main classes, according to the attention required by each.

1. Those who are suffering from physical injuries due to high explosives, incendiaries, or inhaled gas but who are not contaminated with persistent vesicants.
2. Those who are suffering from such physical injuries and are also contaminated with persistent gas.
3. Those who have been contaminated with persistent gas and require medical treatment but are not otherwise injured.

All three classes are dealt with by a single organization which combines the normal type of ambulance and hospital service for the treatment of accidents with special arrangements for treatment of contaminated persons. The Medical Service should be organized to provide separate accommodations for women, and arrangements made to ensure that contamination by persistent gas will not be spread to noncontaminated casualties. Since first aid for vesicant gas cases should be given within 10 min. of contamination, these casualties should be cleansed at the earliest possible moment.

As regards service to the general public, it is desirable to draw a line of demarcation between the cases handled by a public gas cleansing center (Chap. XIII) and those handled by the First Aid and Medical Service. In general, *unwounded* contaminated persons who do not require any therapeutic treatment as a result of contamination are handled by gas cleansing centers, whereas those who are wounded or require such therapeutic treatment are handled by the First Aid and Medical Service. In certain cases, such as in factories and large industrial enterprises who maintain their own facilities for handling wounded and contaminated personnel, the functions of gas cleansing centers and first aid stations may be combined in a single unit. Where these functions are performed in separate stations, it is desirable that these stations be located either adjoining each other or as close together as practicable, so that slightly wounded contaminated personnel can be cleansed in the cleansing center before entering the first aid station. However, seriously wounded and contaminated persons must be cleansed and medically treated in a first aid station.

Organization.—In each city the First Aid and Medical Service is directed from a central headquarters with a medical officer in general charge, assisted by a suitable staff, to enable him to direct and coordinate the activities of the Service in each urban community. If the community is a city of over 100,000 inhabitants, it should be subdivided into divisional areas of approximately

100,000 inhabitants each, and a divisional medical officer placed in charge of each area.

In large cities (over 500,000) the First Aid and Medical Service should be organized as a separate service under the Air Raid Precautions Department. In small cities (under 100,000), the First Aid and Medical Service should function under the regular city health department. In cities between 100,000 and 500,000, either arrangement may be adopted depending upon the local situation.

Functioning under the medical officer in charge, the First Aid and Medical Service consists in the following:

1. *First aid parties*, operating from a central depot or first aid posts in each district and dispatched to any place where air raid casualties occur.
2. *First aid depots*, where first aid parties are based and from which they operate.
3. *First aid posts*, where slightly wounded or gassed persons can receive treatment, with a change of clothing, if necessary. Here casualties are sorted out and segregated according to degree of injury and sent to hospitals if further treatment is required.
4. *Casualty clearing hospitals*, where more serious cases can be taken by ambulances and treated until fit for transfer to base hospitals.
5. *Base hospitals*, for treating cases evacuated from casualty clearing hospitals.
6. *Air ambulance service*, for moving stretcher cases from places where casualties occur to first aid posts or casualty clearing hospitals and from these stations to base hospitals.
7. A *clothing decontamination arrangement*, for decontaminating clothing removed from casualties.
8. A *clerical force*, for keeping records of casualties, their property, and their places of treatment.

First Aid Parties.—The duties of these parties are to proceed to the casualties occurring in their district as rapidly as possible and to render such first aid to the injured as is urgently required. They may remove gas-contaminated clothing, stop hemorrhages, dress wounds, set broken bones, etc. After administering such measures of first aid as are required, they direct or carry the casualties to the nearest first aid post. Personnel forming first aid parties should be thoroughly trained in the technique of rendering first aid to the injured, including those contaminated by gas.

Such trained personnel can generally be furnished initially by large city hospitals and the American Red Cross Society; additional personnel must be trained by the First Aid and Medical Service.

First aid parties should consist of four men, each equipped with a gas mask, protective clothing, and a first aid pouch. In addition the party should carry a stretcher and blanket, six spare gas masks, and a surgical haversack containing the usual materials for rendering first aid to the injured. Approximately 20 parties should be provided for each 100,000 population, exclusive of parties organized and maintained by industrial and commercial enterprises or other private concerns; and these parties should be supplemented by a trained reserve of not less than 25 per cent, which can be called into service as required. Sixteen parties should be stationed at first aid posts scattered throughout the district, and 4 held in general reserve in a central depot where they will be readily available. At least two first aid parties should be stationed at each first aid post, so that one will always be on duty, while the other is resting or out on call.

First Aid Depots.—A first aid depot is a central station in each district, from which reserve first aid parties can be sent to reinforce any locality where a large number of casualties occur. The depot includes facilities where members of such parties can wash and decontaminate themselves when coming off duty. Such facilities should be similar to those of a public gas cleansing station (see Chap. XIII). First aid personnel also obtain their meals and sleep at the depot when not on duty. In addition, the depot has storage accommodations for the equipment, supplies, and motor transportation of all parties based thereon and is in communication by telephone and messenger with the headquarters of the First Aid and Medical Service, so that the movements of the parties can be controlled by a central authority. In general, a first aid depot should be centrally located so that any part of the district that it serves can be reached in a short time. As a rule, such depots in thickly populated cities should not be more than 2 miles apart.

Each depot should be splinter- and gas-proof. Where other buildings are not available, empty dwelling houses of moderate size may serve as satisfactory depots for first aid parties, provided that suitable facilities are installed for gas cleansing and decontamination.

There is an officer in charge of each depot who is responsible for arranging hours of duty and relief, for seeing that parties are sent out as required, and, in general, for supervising the operation of the depot.

First Aid Posts.—Since these posts must handle all kinds of casualties, they should have combined facilities for first aid treatment and for decontamination of personnel. A sufficient number of posts should be provided in each urban community so that nobody would have to travel over ½ mile to reach the nearest one. In less thickly settled localities, the distance between posts can be somewhat increased, but not to such an extent as to require more than 10 min. to reach a post.

First aid posts should be arranged and equipped for the treatment of the three types of casualties mentioned on pages 190 and 191, which are not sufficiently serious to need to be taken direct to a hospital by ambulance. In addition, some serious cases will also be handled, when the gravity of the injury is not recognized at first or when an ambulance is not available for transport to a hospital.

Since separate accommodations must be provided for both sexes and for contaminated and uncontaminated cases, a considerable floor area is required for a first aid post. Thus, a small post, capable of handling a total of 20 patients of either sex at a time, requires a floor space of approximately 2,500 sq. ft., exclusive of offices, storerooms, and accommodations for the staff. Similarly, a large post, having a capacity of 40 patients of either sex at a time, requires about 4,000 sq. ft. of floor space. In addition, accommodations for two first aid parties should be provided, as well as housing for ambulances operating out of the post.

Figure 34 shows a typical layout for a small first aid post for men and women of the three separate types of cases mentioned on pages 190 and 191. Larger sized posts should follow the same general scheme on an increased scale. It will be noted in Fig. 34 that the entrances to the middle section A_1 for uncontaminated patients, is well away from the entrances to contaminated sections B_1 and C_1 and that the contaminated rooms B_1 and C_1 can be properly sealed off from the rest of the building.

It is preferable that a complete first aid post be housed in one building as indicated in Fig. 34. Where this is not possible, separate buildings can be provided for each sex. Alternatively the

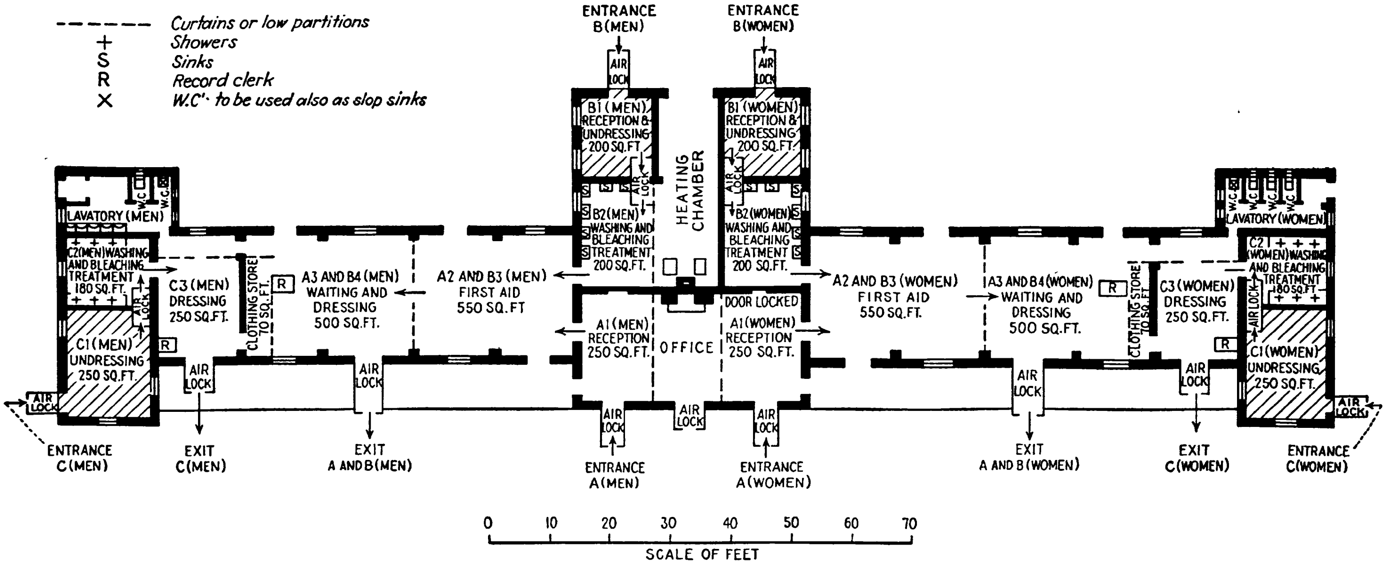
- - - - - - Curtains or low partitions
+ Showers
S Sinks
R Record clerk
X W.C'. to be used also as slop sinks
ENTRANCE B(MEN)
ENTRANCE B(WOMEN)
AIR LOCK
B1 (MEN) RECEPTION & UNDRESSING 200 SQ.FT.
B1 (WOMEN) RECEPTION & UNDRESSING 200 SQ.FT.
HEATING CHAMBER
B2 (MEN) WASHING AND BLEACHING TREATMENT 200 SQ.FT.
B2 (WOMEN) WASHING AND BLEACHING TREATMENT 200 SQ.FT.
LAVATORY (MEN)
LAVATORY (WOMEN)
W.C.
C2 (MEN) WASHING AND BLEACHING TREATMENT 180 SQ.FT.
C2 (WOMEN) WASHING AND BLEACHING TREATMENT 180 SQ.FT.
C3 (MEN) DRESSING 250 SQ.FT.
C3 (WOMEN) DRESSING 250 SQ.FT.
CLOTHING STORE 70 SQ.FT.
A3 AND B4 (MEN) WAITING AND DRESSING 500 SQ.FT.
A3 AND B4 (WOMEN) WAITING AND DRESSING 500 SQ.FT.
A2 AND B3 (MEN) FIRST AID 550 SQ.FT
A2 AND B3 (WOMEN) FIRST AID 550 SQ.FT.
DOOR LOCKED
A1 (MEN) RECEPTION 250 SQ.FT.
OFFICE
A1 (WOMEN) RECEPTION 250 SQ.FT.
C1 (MEN) UNDRESSING 250 SQ.FT.
C1 (WOMEN) UNDRESSING 250 SQ.FT.
R
ENTRANCE C(MEN)
EXIT C(MEN)
EXIT A AND B(MEN)
ENTRANCE A(MEN)
ENTRANCE A(WOMEN)
EXIT A AND B (WOMEN)
EXIT C(WOMEN)
ENTRANCE C(WOMEN)
0 10 20 30 40 50 60 70
SCALE OF FEET

FIG. 34.—Small first aid post. (The shading shows portions in which gas vapor might collect.)

first aid portions (Sections *A* and *B*) can be housed in one building, and the accommodations for the contaminated unwounded cases (Section *C*) in another. Whatever arrangement is adopted, the separate buildings constituting one complete post (for men and women) should be not more than 100 yd. apart and within sight of one another.

In addition to the foregoing, the following general points are of importance in arranging a first aid post:

1. All buildings should be gas-proof and splinter-proof and all external doors provided with air locks.
2. Provision must be made for preventing flying fragments of glass from broken windows.
3. All lights must be obscured at night, so that none are visible from outside, except a dim sign indicating the position of the post.
4. Partitions between rooms can be of light and improvised construction and need not extend higher than 7 ft., except where they separate accommodations for contaminated patients from those of uncontaminated patients.
5. Accommodations for contaminated patients should be so arranged as to prevent spread of contamination to accommodations for uncontaminated patients.
6. Alternative sources of light and water should be provided in case the external supply should be cut off by bomb damage. Wood or coal fires for heating water, oil lamps, and local storage of water will serve when more elaborate facilities cannot be made available.

Since there will be only a limited number of buildings in any locality that are adapted to serve as satisfactory first aid posts, even with considerable internal alteration, it is important that such buildings as are favorable be earmarked and plans prepared in advance for fitting them up. In selecting buildings for such posts, consideration should be given to schools, public baths and halls, concert and dance halls, small motion-picture theaters, parish halls, space under grandstands, golf clubhouses, etc.

In less densely populated suburban and rural areas surrounding cities, the need for first aid treatment of air raid casualties may be more promptly and economically met by the use of *mobile first aid posts* which are normally contained in one or more motorized units and are adapted to be set up and operated as and where required. Large motor vans or busses can be fitted up as complete mobile units and stationed at convenient points so that they may be quickly dispatched to wherever air raid casualties occur.

A first aid post is normally manned by an officer in charge with 70 to 110 assistants, according to the size of the post. A large post is required for an area containing a population of about 50,000; a medium post, for an area having about 25,000; and a small post, for an area having about 12,500. In each post, approximately half of the assistants should be men and the other half women; and, of each sex, about one-half should be skilled in first aid and anti-gas treatment, and the other half unskilled personnel, such as stretcher-bearers, doormen, clerks, storekeepers, etc.

It will seldom be practicable to provide a resident physician in charge of a first aid post, but it is essential that a civilian medical practitioner be available on call to any post for a serious casualty whose condition requires more than first aid treatment and who is unfit for removal to a casualty clearing hospital. To meet this requirement, several posts in any district can be allotted to a physician resident in that district who will be available to respond to emergency calls.

Casualty Clearing Hospitals.—These hospitals should be located in the areas where casualties are most likely to occur. In cities liable to air attack, casualties will undoubtedly be heaviest in the most thickly populated and congested districts, and it is in such districts that casualty clearing hospitals are most urgently needed. In general, the most feasible plan for establishing casualty clearing hospitals is to utilize the existing local hospitals and to augment them by installing special facilities for the purpose. Local hospitals so used must be evacuated of all patients who can be moved to outlying hospitals in safer localities; thereafter, no patients, whether air raid casualties or otherwise, should be accepted for lengthy treatment when they can be taken elsewhere. During air raids, casualties should normally be removed to base hospitals as soon as they are in condition for transfer, and no cases should be retained in casualty clearing hospitals except those unfit to move. This is necessary to clear the beds for new cases and to place those undergoing further treatment in safer localities.

As raids may cause disorganization of existing hospitals by the large number of casualties that occur or by damage to buildings and essential utilities, it is advisable to ascertain the number and distribution of hospital beds in each city area and prepare a plan for the distribution of casualties. To prevent overcrowding of casualty clearing hospitals, first aid posts should be carefully supervised to see that only cases that require hospital treatment are sent to hospitals. It is also advisable to establish in each hospital an outpatient ward where less serious cases can be treated.

Casualty clearing hospitals must be prepared to handle exactly the same class of casualties as a first aid post, since it is unreasonable to expect injured persons not to proceed direct to a hospital when it is nearer than the nearest post. However, hospitals should not be expected to care for uninjured persons who are merely contaminated; such persons should be sent to the nearest first aid post if they cannot take care of themselves at home.

Casualty clearing hospitals should be equipped to cleanse injured patients who are contaminated before admitting them into the wards. Accordingly, as in the case of first aid posts, accommodations for handling both wounded and contaminated persons of both sexes will be required, as well as administrative arrangements for the reception and processing of gas-contaminated persons. In addition, the usual operating rooms and beds should be available for the more serious cases. The hospitals should be both splinter- and gas-proof, at least in those parts in which essential services are maintained.

Casualty clearing hospitals will require in addition to medical personnel and the usual hospital staff, specially trained decontamination personnel, with adequate reliefs for all doctors, nurses, orderlies, stretcher-bearers, and other hospital employees. The staffs should be equipped with gas masks and protective clothing.

Base Hospitals.—Base hospitals should preferably be located in the outlying and safer parts of cities but should not be so far away from the populous centers as to encounter transport difficulties. As most casualty, emergency, and general hospitals are in thickly populated areas, they should not be used as base hospitals for air raid casualties. Base hospitals should preferably be established in mental or infectious disease hospitals, sanitariums, and public institutions which are generally located in the suburbs or rural districts. It may also be necessary in certain districts to select buildings that are not normally used as hospitals.

A base hospital should have the same organization, equipment, and staff as a casualty clearing hospital, including means for handling contaminated patients in certain wards. More extensive bed wards are, however, required to accommodate serious cases requiring lengthy treatment.

Ambulance Service.—A considerable number of ambulances will be required for transporting casualties from first aid parties and posts to casualty clearing and base hospitals. Suitable arrangements should accordingly be made for mobilizing all ambulances available in the district and supplementing these by others from the local authorities, as required. A well-organized ambulance service is an essential part of the First Aid and Medical Service and should be organized and operated by each district headquarters. It is important that ambulance depots be established at convenient places from which they can be quickly dispatched to collect casualties wherever they occur. Such depots should also be in telephone communication with the headquarters of the First Aid and Medical Service and with the first aid posts and hospitals that they serve.

An adequate number of ambulance drivers should be trained and equipped with gas masks and protective clothing. All ambulances should be fitted or adapted to take a standard Army stretcher.

Clothing Decontamination Arrangement.—A special arrangement is required for the decontamination of clothing and equipment removed from casualties and that used by members of the First Aid and Medical Service. As a rule, all decontaminated clothing and equipment are sent to a decontamination center which consists essentially in a laundry with machines especially adapted for decontamination work. Trained personnel are required for handling and treating contaminated clothing and equipment, and special transport is needed for carrying such contaminated articles, because of the risks involved. Decontamination centers can frequently be best established by taking over large steam laundries and specially organizing and equipping them for decontamination work (see Chap. XIII).

Clerical Force.—Qualified clerical staffs should be provided to keep proper records of casualties and their treatment at every first aid post and hospital, including a central records section at the headquarters of the First Aid and Medical Service. These clerical forces also provide for the custody and handling of patients' clothing and valuables.

Finally, the First Aid and Medical Service in each district should provide for lending and receiving assistance from neighboring districts, in serious emergencies when the facilities of any one district may be overtaxed.

CHAPTER X

FIRE PRECAUTIONS SERVICE*

General.—In Chaps. II and V, we discussed the damage wrought by incendiary bombs and the methods of protection against this danger. In this chapter, we shall now consider the *organization* required in each city to protect the community from incendiary attack. The problem of protecting a city against incendiary attack differs from ordinary peacetime fire protection chiefly in the much larger number of fires that may occur simultaneously in any given area and in the peculiar action of incendiary bombs. Under normal peace conditions the organization and equipment of a permanent city fire department are rightly based on the premise that numerous fires will not occur at the same time. Long years of experience have shown the maximum number of fires that may occur simultaneously in any given area, and this is but a very small fraction of those which may be produced in the same area by a single incendiary attack. War conditions, therefore, introduce a fundamentally new factor which greatly affects the whole basis of organization and equipment of permanent municipal fire departments and seriously complicates the problem of water supplies. In time of war, each separate fire in a congested area must be regarded as a potential conflagration, and it is accordingly important to frame a wartime fire-fighting organization with a view to dealing with as many fires as possible in their incipient states.

As we have shown in Chaps. II and V, small (2-lb.) electron incendiary bombs will normally penetrate all ordinary roofs and generally start fires in the attics or top floors of buildings, often without the occupants of the building being aware of the fact. These bombs produce a very intense heat, and they cannot be extinguished with water. On the contrary, the application of water to the bomb itself may be dangerous and involve risk of explosion. Though much can be done by the ordinary householder to control small electron bombs with sand, it must be expected that, when such a bomb falls among inflammable materials or on an ordinary wooden floor, a considerable fire may result in a short time. To meet this situation, effective fire-fighting appliances capable of dealing with such fires and sufficient supplies of water should be quickly available for use at numerous points.

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* The information contained in this chapter is based largely upon current British practice and might not necessarily be followed by the United States.

Measures for protecting a city against incendiary attack embrace two general categories of action: (1) *precautions* for *preventing* the occurrence and spread of fires; (2) *provisions* for *simultaneously fighting* and subduing a large number of fires that have occurred as a result of incendiary attack.

Preventive Measures.—Measures of the first category are largely the same *preventive measures* that should be taken in time of peace to reduce the fire hazards in the community, plus the special measures described in Chap. V for dealing with incendiary bombs in the home, small communal dwellings, shops, and business premises. In this connection, the local authorities should make every effort to encourage all householders and occupants of shops, offices, industrial establishments, and large communal dwellings (hotels, apartments, and tenements) to take all possible precautions against the risk of fire, to provide themselves with their own fire-fighting equipment, and to see that water reserves are available in emergency. The only additional public organization required for fire prevention in time of emergency is a system of *fire lookouts* to keep all inflammable buildings under close watch and notify occupants and the fire department whenever a building is observed to be struck by an incendiary bomb.

Fire lookouts are men specially detailed for this duty and stationed at favorable observation points throughout the city, from which they can clearly see the roofs of buildings within the area they are charged with watching. Only men who are especially vigilant, dependable, and accurate in observing and reporting the fall of bombs should be selected as fire lookouts. Each *lookout post* should be in telephone communication with the nearest fire station and should be equipped with chemical fire extinguishers and light portable hand appliances for fighting fires. At least two men, and preferably three, should be stationed at all times during air raids at each fire lookout post, so that while one is on duty the other can be sleeping or resting. Three shifts should be provided for each post during periods of frequent air raids. To enable them to assist householders in extinguishing incipient fires, fire lookout posts are generally equipped with a two-man portable manual fire pump with 100 ft. of ¾-in. hose; portable hand pumps with hose and spray nozzles; chemical (2-gal.) fire extinguishers; and the usual complement of axes, spades, crowbars, water and sand buckets, etc.

The scale upon which fire lookout posts should be provided depends primarily upon the area that can be watched from each post and the vulnerability of the buildings in the area to incendiary attack. On an average, one lookout post per city block should be sufficient in a residential district, provided that the post is properly located between the backs of the houses near the center of the block and the police and Air Raid Wardens assist in watching the houses from the streets. In commercial districts of greater fire hazard, two or three fire lookout posts per block may be necessary, in addition to fire watchmen employed by the owners of factories and other industrial premises. In the downtown business districts where many tall office buildings are situated, a system of roof lookouts should supplement the city fire lookout posts. These men should be employed by the owners of the buildings on which they are stationed.

Combative Measures.—Measures for simultaneously combating and subduing fires that have occurred as a result of incendiary attack embrace the following:

1. Appointment of a Chief of Fire Precautions Service, and provision of a technical and administrative staff for:

   a. Working out the measures that should be taken, in time of emergency, to cope with the danger of incendiary attack.
   b. Supervising the execution of formulated planes.
   c. Providing necessary accommodations and material to implement such plans.

2. Augmentation of the permanent city fire department, by increasing the number of fire companies and heavy fire-fighting appliances.

3. Organization of auxiliary fire stations, with companies to man them and lighter fire-fighting equipment to implement them.

4. Organization of a system of mobile fire patrols, having units equipped with light, portable appliances for dealing with fires in their incipient stages.

5. Provision of additional stocks of hose and miscellaneous fire-fighting equipment for the foregoing units and other purposes.

6. Recruitment and training of auxiliary and reserve personnel for the foregoing.

7. Provision of supplementary means of communication for permanent and auxiliary fire stations and patrol units.

General Scheme of Organization.—The additional fire-fighting forces needed for the protection of a city against incendiary attack may be organized either as a part of the permanent city fire department or as a separate service, functioning under the Director of Air Raid Precautions. In a small or medium sized city (less than 500,000 population), it is probable that the best results can be obtained by the adoption of the former scheme; for large cities (over 500,000), the latter scheme seems preferable. This is due partly to the fact that in the smaller cities the additional fire-fighting facilities required for war emergency can be obtained by a requisite expansion of the regular city fire department, without overloading the directing head and creating an unwieldy organization, whereas in the larger cities the reverse would be the case. Also, since the emergency fire-fighting force has to work hand in glove with the Rescue and Debris Clearance Service, the First Aid Service, and the Decontamination Service, better coordination of these various activities can be obtained if they all work under a common direction. This advantage can be best secured by making the emergency fire-fighting force a separate unit under the Air Raid Precautions Department (ARPD).

Where the emergency Fire Precautions Service is organized as a unit, separate from the permanent city fire department, it is, of course, essential that it work in the closest collaboration with that department, in order that the maximum effectiveness of the two fire-fighting forces can be realized in an emergency.

Whether the Fire Precautions Service is a part of, or separate from, the permanent fire department, it must have a directing head, assisted by a technical and administrative staff, for performing the duties mentioned above. If the Fire Precautions Service is a part of the permanent city fire department, its head should be one of the assistant chiefs of that department, reporting to the Chief of the Fire Department and supervising all the activities of the *emergency* fire-fighting forces. If the Fire Precautions Service is created as a *separate* unit, under the ARPD, its head would be known as the Chief of the Fire Precautions Service and he would report to the Director of Air Raid Precautions.

Under either arrangement, one of the first duties of the new service would be to make a careful fire-risk survey and study of the whole city, with a view to classifying the various districts in the city according to their need for additional fire protection in time of war. The results of this study will indicate the scale of the provision to be made under the various heads, such as auxiliary fire stations, patrol units, personnel and equipment, and additional water supplies. These in turn determine the size of the emergency fire-fighting force.

In studying the additional needs for fire protection, one of the most important steps is to survey and classify the various districts of the city according to the element of fire risk. Thus, it is obvious that large factories, warehouses, shops and stores, munitions plants, docks, railroad depots, lumberyards, oil refineries, and storage yards, etc., constitute the most serious fire risk and should be given the maximum possible fire protection. The next most serious fire hazards are small factories, medium sized warehouses, shops and stores, storage yards (other than lumber), large garages, small oil depots, etc.: these should receive the next most extensive fire protection. Finally, residential and small shop areas are the least hazardous and require the minimum fire protection.

In determining the number and location of auxiliary fire stations and mobile fire patrols, the principal factors are: (1) street mileage; (2) the area to be covered; (3) its classification as to fire risk; (4) the degree of exposure to air attack.

The number of mobile fire patrols to be provided in any community depends to some extent upon the intensity of the fixed lookout post system. Under average conditions, with fixed lookout posts provided as indicated above, one mobile fire patrol should be allotted for every 2 miles of streets in residential sections, and one auxiliary fire station for every five mobile patrols. Areas containing small factories and medium sized commercial installations will require twice, and areas having large factories and hazardous industries four times, as many fire patrols and stations as a residential area of the same size. The mobile fire patrols and auxiliary fire stations should be organized so as to be available on call at any hour of the day or night. For areas most exposed to air attack, this means that they will have to be manned on a 24-hr. basis during periods of intensive air raids.

Augmentation of Permanent Fire Department.—In organizing a fire-fighting force for a war emergency, the first step is to expand the permanent city fire department by supplying such additional personnel and fire-fighting appliances as can be absorbed by the fire department with its existing fire stations and other installations. The purpose of this step is to raise the permanent fire department to its maximum level of effectiveness within the framework of its existing facilities. This development should not take the form of building additions to existing fire stations, for such action will result in concentrating too many units in one place, where they may be put out of action by a single bomb. At the same time, the number of new fire stations added to the permanent city fire department should be limited to those that can be accommodated within the existing organization of that department without overloading the directing headquarters and producing an unwieldy force. All new fire stations required beyond that point should be incorporated into the emergency Fire Precautions Service. A careful study of the local situation and the present capacity of the permanent fire department will indicate the degree of expansion of that department which is desirable for a war emergency.

Organization of Auxiliary Fire Stations.—Having determined the maximum number of fire stations that can be efficiently handled by the permanent city fire department, the next step is to organize and locate the number of auxiliary fire stations required for each section of the city, on the basis indicated above.

Auxiliary fire stations should be equipped with heavy or light fire-fighting appliances, in the average ratio of 1 of the former to 2 of the latter. The personnel required for an auxiliary fire station depends upon the number of men needed to man the type of fire-fighting equipment assigned to the station. In general, a heavy pump station will demand a proportionately larger complement of personnel than a light pump station.

Heavy pump units are required for direct attack upon large fires and for relaying water in large quantities over considerable distances from static supplies. For such purposes a standard pump of not less than 700 gal /min. at 100 lb. /sq. in. pressure, with four delivery outlets, should be used. These pumps can be mounted on a frame that is detachably bolted to a 2½-ton motor truck or small river steamer or barge, thus forming an emergency fire engine or fireboat. Each such fire engine and -boat is equipped with 1,000 ft. of standard fire hose and the usual complement of tools and fire-fighting equipment used by regular fire-fighting companies. Each truck or river boat is assigned to a heavy pump company and carries the complete company, both personnel and material.

Light pump units are designed for dealing with medium sized fires, requiring about 300 gal. of water per minute. For this purpose, a trailer pump of 350 gal. /min. and 100 lb. /sq. in. pressure, with two delivery outlets, is used. Two of these pumps, each towed by a 1½-ton truck, are assigned to a light pump company. The trucks carry all the personnel and equipment of the company. The trailer pumps can be maneuvered over or around obstructions in the streets that would ordinarily block a heavy-duty pump. Each trailer pump unit has 800 ft. of standard fire hose and the usual complement of accessory fire-fighting tools and equipment.

In general, only one heavy or light pump company should be assigned to an auxiliary fire station, in order to secure maximum distribution and avoid the risk of two or more units being damaged or destroyed by a single bomb. A heavy or light pump company can be accommodated in an average sized public garage and should be located at a suitable point where it can quickly respond to calls brought in by mobile fire patrols or reinforce permanent fire-fighting units, in an emergency.

Organization of Mobile Patrols.—In addition to auxiliary fire stations, there should also be a *mobile patrol system*, covering the whole built-up area of the city, to ensure prompt discovery of outbreaks of fire and institute immediate measures to subdue any fire, even in vacant premises. These patrols are organized in units that are based on permanent and auxiliary fire stations, and the patrolling system is laid out in each built-up area so that every street is kept under frequent surveillance during air raids. The fire stations are kept informed of the situation in each patrol area, and no patrol has far to go in order to call heavier fire-fighting appliances from the stations. The patrols are provided with motorized station wagons or light trucks which are equipped for carrying a portable pump and crew, together with the usual complement of fire-fighting appliances, including 500 ft. of standard fire hose, chemical extinguishers, tools, etc. The pump is motor driven, with two delivery outlets, and a capacity of about 120 gal. /min., at 80 lb. /sq in. pressure. It may be either detachably mounted in the truck or on a two-wheel trailer, adapted to be drawn behind the truck.

Stocks of Hose and Miscellaneous Equipment.—Large stocks of fire hose will be needed for use with fire-fighting units and for relaying supplementary supplies of water where fire hydrants are not available. Accordingly, there should be accumulated and kept on hand ample reserves of hose so as immediately to replace any that is damaged or becomes unserviceable during an emergency. In addition to fire pumps and hose, there will also be required fire-fighting appliances and equipment for auxiliary fire station companies, mobile patrols, and fire posts. All these supplies should be available before the outbreak of an emergency. The requirements for all such material should, accordingly, be carefully estimated and the material acquired under the local emergency fire protection plan.

Recruitment and Training of Personnel.—With the establishment of auxiliary fire stations and mobile patrols and the acquisition of fire-fighting appliances and equipment, it is essential to procure and train the necessary personnel to man the stations and appliances, to form the patrols, and to act as drivers and messengers. To provide for ordinary losses and casualties and for unexpected contingencies, it is necessary to obtain and train at least twice the number of men that would ordinarily be required merely to man the instrumentalities of the Fire Precautions Service.

The personnel required, in accordance with the general plan outlined above, will fall into the following categories:

1. Men who have had fire department experience and who agree to join a fire company in an emergency.
2. Men without previous fire department experience but who offer their services to the Fire Precautions Service and are trained as auxiliary firemen for duty in an emergency.

In view of their previous training and experience, ex-firemen are particularly valuable if they are still able-bodied and can rejoin a fire company for emergency service. Even if no longer fit for active fire fighting, these men may be employed in other fire station duties and to assist in training auxiliary firemen. They should be enrolled as reservists and medically examined annually. They may be called up periodically in peacetime for refresher training and should be paid a small annual retaining fee. In an emergency, they would be called up as full-time firemen and paid accordingly. Fire Precautions Service authorities should prepare a list of suitable men for fire reservists and revise it annually. However, the number of men who will be available as reservists will be comparatively small, and it will therefore be necessary to recruit and train large numbers of men for duty as auxiliary firemen.

Steps should accordingly be taken to recruit and train the requisite number of auxiliary firemen to complete the complement required for the various emergency duties of the Fire Precautions Service. It is necessary that all auxiliary firemen receive a peacetime course of instruction comprising fire drills with the various appliances and instruction in fire prevention, fire fighting, anti-gas, first aid, incendiary bombs, smoke conditions, and the war organization generally. Upon satisfactory completion of the prescribed course of training, auxiliary firemen should receive a small bonus, provided that they agree to render service as firemen when required in an emergency.

Under emergency conditions, auxiliary firemen will be assigned to an auxiliary fire status and employed as members of fire station crews or on mobile patrol duty.

Other personnel required as messengers, drivers, watch-room attendants, telephone operators, electricians, and for other miscellaneous duties may be employed from among both men and women who are fitted for such duties.

Emergency Means of Communication.—Since the public telephone service and the special communication systems of the regular city police and fire departments may be interrupted or entirely put out of action by bomb damage, it is necessary to provide additional emergency means of communication, to guard against this contingency and to serve the additional auxiliary fire stations and patrols of the Fire Precautions Service. One of the first steps in this direction is to augment the facilities for receiving calls at permanent fire stations. This may be done by increasing the number of street fire-alarm boxes and also the number of commercial telephone lines to each station.

The next step is to make the same provision for auxiliary fire stations and fire patrol reporting stations and to see that these are fully interconnected with the communications net of the permanent fire department. Arrangements should also be made for increasing, in an emergency, the telephone facilities at auxiliary fire stations by utilizing the regular fire-alarm and police boxes near these stations.

For each station, a messenger service should be organized for use in case the public telephone service goes out of action. It is also desirable to arrange a service, with motorcycle and bicycle messengers, operating from permanent and auxiliary fire stations, to convey messages to firemen already engaged at a fire and to pumping stations, electric power plants, gas works, etc.

Finally, each fire engine and fireboat should be equipped with a two-way short-wave radio set for communication with fire stations and the headquarters of the Fire Precautions Service. This will be of great advantage in dispatching fire units out on call to other places where their services are required or to a more serious fire.

Augmentation of Water Supplies.—One of the most important matters to be covered in any local plan of fire protection for a war emergency is the provision of adequate supplies of water. It is, of course, essential that sufficient water be available on the spot in dealing with outbreaks of fire. Where numerous fires occur simultaneously and many fire hydrants are open at the same time, the pressure in the city mains drops to such an extent as seriously to reduce the normal flow of water. Also, bomb damage may burst one or more water mains and completely shut off the water supply to the area they serve. It is accordingly of the greatest importance to conserve the supplies of water in the mains and make the fullest possible use of auxiliary supplies for fighting fires in their incipient stages. To this end, every emergency fire protection plan should include provision for water in containers at fire posts in all business premises and for urging householders to have water, in buckets, bathtubs, and sinks, available on their premises in an emergency. Also, each mobile fire patrol should be equipped with a small tank cart or trailer holding sufficient water for the first attack on a small fire.

To prevent wastage of the regular city water supply, arrangements should be made to ensure the cutting off of areas where water mains are ruptured by bomb damage. The areas from which water is thus cut off can be restricted by installing additional control valves in the water distribution system of the city.

The following means may be utilized for supplementing normal water supplies in an emergency:

1. All possible alternative sources of water, such as canals, rivers, lakes, ponds, and even swimming pools, should be utilized wherever possible.

2. Water can be stored in underground tanks and by flooding cellars.

3. All practicable means of conveying water from static supply sources should be considered, and arrangements made for utilizing water carts, tank trucks, and railroad tank cars for hauling water, to supplement long pumping hose lines. In some cases, light 6-in. steel piping can be laid along roadways for conveying water to areas where no fire hydrants exist.

4. Water pumping boats and barges can also furnish large auxiliary supplies of water to areas adjacent rivers and harbors.

After a study of the foregoing expedients a comprehensive emergency water supply plan should be drawn up for each community and steps taken to see that it is effectively carried out in time of emergency.

Fire Service in Rural Areas.—The likelihood of areas outside the cities being subjected to serious incendiary attack is not nearly so great as in the case of urban areas, nor is the damage from such attacks likely to be so widespread in the event of attack. Nevertheless, in outlying zones around large cities and in areas surrounding munitions factories and other military targets, the danger of damage from incendiary bombs is sufficient to warrant the application of the preventive measures mentioned in this chapter and the use of the combative means described above, at least on a reduced scale.

The first requirement is provision for not less than one light pump fire unit, to be available on first call to each rural community within 15 to 20 min. and to each small town within 10 to 15 min. These pump units should be organized in essentially the same manner as those for cities (page 204) except that they should carry about 1,000 ft. of additional hose. In rural districts where fire risks are unusually high, a second light pump unit should also be within approximately the same call; and, in all districts, a *support-*

ing unit of similar capacity should be within reach of any portion of the district within 30 min. after receipt of a call.

In each small town (less than 2,500 inhabitants), beyond 5 miles from a first call, a light pump unit should be provided with one or more light trailer pump units (see page 205); and fire parties with hand appliances should be organized in each smaller village, township, and hamlet. Provision should be made for the storage of pumps and all accessory fire-fighting gear at specific points from which the area to be served is readily accessible. Each such station should be in charge of a designated individual whose location and telephone number are known to all living in the area. Other members of the unit should also live near by and be readily available, so that the unit may respond to a fire call within 5 min. after its receipt.

Fire protection plans of rural communities should be coordinated by the county authorities and should be based upon the principle of mutual assistance between neighboring districts.

CHAPTER XI

RESCUE AND DEBRIS CLEARANCE SERVICE*

General.—Recent experience in Europe has shown that air raids with high explosive and incendiary bombs may cause widespread damage to buildings, especially in densely built-up areas of large cities. When high explosive bombs are used, not only are the buildings themselves wholly or partly demolished, but frequently the occupants are trapped and the adjoining streets blocked by the resulting debris. The latter is particularly true where multistory masonry buildings are located abutting or close to the sidewalks of the streets. High explosive bombs may also rupture water and gas mains and thus add extra dangers to street traffic. When incendiary bombs are used against such buildings, the roof, floors, and interior walls are generally destroyed and the outer walls left standing. These walls are very unstable and constitute a serious hazard to traffic in the adjoining streets. It is, therefore, necessary to shore them up or remove them entirely before the streets can be used with safety.

To meet such situations, provisions must be made to

1. Rescue persons who are trapped in damaged or collapsed buildings and to recover dead bodies from such buildings.
2. Clear streets of debris from damaged or collapsed buildings.
3. Shore up or remove walls left standing in an unstable and dangerous condition.

In normal times, these duties are generally performed by police and fire departments of cities; but in times of war when cities are subjected to large-scale air attacks, it is necessary to provide a special organization for this purpose. This is known as the Rescue and Debris Clearance Service and is a part of the Air Raid Precautions Department (ARPD). It works in close collaboration with other emergency services, such as the First Aid and Medical, Decontamination, Air Raid Warden, and Fire Precautions Services.

Organization.—The Rescue and Debris Clearance Service consists of central headquarters, one or more divisional headquarters, and several depots, out of which operate a number of rescue and debris clearance squads.

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* The information contained in this chapter is based largely upon current British practice and might not necessarily be followed by the United States.

The *central headquarters* consists of a Chief of Service, assisted by a staff and clerical force. The Chief directs the general operation of the Service and is responsible for the recruiting and training of its personnel. He functions under the direct supervision of the Director of Air Raid Precautions, and works in close collaboration with the chiefs of the other emergency services mentioned above, as well as the heads of the local municipal police, fire, and street maintenance departments.

The *divisional headquarters* consists of a superintendent and staff, at the headquarters of each division of the city, generally corresponding to an area containing 100,000 population.

The Rescue and Debris Clearance Service maintains a *central reserve depot* and four or more operating depots in each divisional area. The central reserve depot is under the control of the division headquarters and is conveniently located in the area it serves. It is used for the training and operation of *reserve* rescue squads and reserve personnel for replacing losses. A reserve of special equipment and supplies for rescue and debris clearance work is also kept on hand at the central depot. The depot is in constant telephone communication with the service headquarters and dispatches *reserve* rescue and debris removal squads to such places as they are needed, in accordance with directions from higher authority. Since rescue and debris squads may become contaminated by working in gassed areas, the central depot should be equipped with means for decontaminating personnel, clothing, and equipment. It also has normal accommodations for housing and messing the personnel assigned to the depot.

An *operating depot* is a station on which a rescue squad is based and out of which it operates. Four such depots are provided for each district having a population of 100,000. These depots are similar in organization to the central reserve depot but are on a smaller scale, since they usually accommodate but one squad. Since rescue squads and first aid parties generally work together, it is an advantage to have the operating depots of the former near the stations of the latter. Each operating depot is in charge of a responsible official and is organized to respond instantly to any calls made on it by higher authorities.

Rescue Squads.—Rescue squads are of two kinds: heavy and light. The former consists of 1 foreman and 7 men, and the latter has 1 foreman and 5 men. Each is equipped with apparatus and appliances appropriate for the work of clearing away debris and dealing with damaged buildings, such as ladders, chain tackles, sheer legs, hydraulic jacks, sledge hammers, crowbars, picks and shovels, etc.; but the heavy rescue squads are more extensively supplied with heavy equipment. In areas where exceptionally large buildings prevail, *heavy* rescue squads are increased in size and are equipped with power-driven appliances for moving heavy beams, concrete slabs, and other objects, and for cutting through steel and concrete.

As a rule, densely populated and heavily built-up areas are provided with four light and two heavy rescue squads per 100,000 population, of which four are normally on duty and two in reserve. Suburban and outlying areas are less heavily manned and depend more upon schemes of mutual assistance between adjacent neighborhoods.

The work of rescue squads is both difficult and dangerous and requires the services of men skilled in handling mechanical equipment and familiar with house-wrecking work. Such men can best be recruited from the construction and building trades, particularly house wreckers, scaffolders, and structural steel erectors. These may be supplemented by riggers and miners. Members of rescue squads should be enrolled and trained prior to the outbreak of an emergency requiring their services. Also, reserves for replacements and augmentation of forces should be earmarked and arrangements made for their prompt availability in case of need.

Rescue squads usually work in conjunction with first aid parties, but the work of the two is separate and distinct. Thus, the former are responsible for releasing persons entrapped in damaged buildings or debris, whereas the latter *remove* injured victims and administer first aid treatment to them. Since rescue squads may have to work in gas concentrations or contaminated areas, they should receive anti-gas training and be provided with masks and protective clothing. Though rescue parties do not perform decontamination work, they may have to deal with contaminated materials in rescuing persons and removing bodies from contaminated buildings. They should, therefore, understand how to deal with such situations without injury to themselves.

Each light rescue squad is provided with a light motor truck for transporting its equipment to the scene of action. In addition, it has a two-wheel trailer which can be dragged by hand over fallen debris and torn up streets that motor trucks could not negotiate. Each heavy rescue squad has a large motor truck, equipped with a derrick, for transporting its equipment.

Duties of Rescue Squads.—The principal duties of rescue squads are

1. Extrication of live persons and dead bodies from damaged buildings and fallen debris.
2. Treatment of damaged buildings that are unsafe and constitute a public hazard.
3. Removal of fallen debris from streets and reopening of blocked highways.
4. Precautions against flooding.

One of the most pressing duties of rescue squads is to *release* persons who are *entrapped* in damaged buildings and fallen debris. As many of such victims may be seriously injured, the work of extrication takes precedence over any other duties of a rescue squad and is immediately commenced upon its arrival at the scene of action. Frequently, this work involves: raising precariously supported beams, floors, etc.; cutting through steel and heavy concrete debris; shoring up portions of structures that are in danger of further collapse; and gaining access to rooms where stairs and corridors have been destroyed. All members of a rescue squad should appreciate the risks of their work and avoid incautious actions which might endanger, not only the entrapped persons, but themselves as well. When access has been gained to an injured person and he is free to be moved, the rescue squad is not responsible for moving him but may assist the first aid party to see that nothing is done to aggravate the victim's injuries. For this reason, rescue squads should have some first aid training.

The next most urgent duty of a rescue squad is to deal with buildings rendered unsafe by bomb damage and that may further collapse at any time. The most precarious situation is usually where tall unbraced walls are left standing close to a street or public highway. The first step is to rope off and exclude the public from the danger areas around such buildings. The unsafe buildings or walls are then braced and shored up or demolished as rapidly as possible. Speed of action is essential in such situations and also in case of damage blocking access to public utilities, such as electric generating plants and railway stations, where service must be restored to the public as soon as possible.

After a building is made safe, in so far as concerns the public, it is not the duty of rescue squads to carry out any repair or restoration work, and the same is true as regards damaged streets, roads, etc.

Since it is vital to the public interest that all streets and roads be kept open to traffic, not only as a public convenience, but to permit the movement of ARP services (fire engines, ambulances, etc.), the removal of fallen debris and reopening of blocked roads is the next most important duty of rescue squads.

Streets and roads may be blocked either by obstructing debris which has fallen from abutting buildings or by bomb craters in the highways themselves. The removal of such obstructions does not present any serious technical problem. It is rather a question of man power; but where air raids are very intense, such work may involve so much labor as to require additional personnel over that ordinarily present in rescue squads. Such additional labor can usually be obtained from the regular city street repair department. All work on streets and roads should be carefully supervised to ensure that the most important streets are cleared first; it should also be coordinated with the regular street maintenance department of the municipal government. It is not the duty of debris clearance squads to repair streets and highways, beyond such emergency measures as are necessary to open the street to traffic. Such work is the duty of repair gangs which form a part of the Demolition and Repair Service (see Chap. XII).

Where damage to streets is accompanied by toxic gas contamination, the services of decontamination squads are first utilized to clear the area before rescue squads and repair gangs go to work.

Rescue squads should not attempt to remove unexploded bombs encountered in their work. The removal of such bombs is highly hazardous and requires special military knowledge and skill. Upon discovering an unexploded bomb, the foreman of a rescue squad notifies the police of its location. He then ropes off the danger area in the vicinity of the bomb and suspends further work in that area until the bomb is removed or exploded by the military authorities.

Precautions against Flooding.—Another duty of rescue squads is to deal with dangers that might arise from floods caused by broken water mains, reservoirs, and dams. The municipal authorities, occupants, and owners of low-lying property that might be flooded in this way should be advised of the danger and what to do in such an emergency. People residing in such areas should be particularly warned not to take refuge in cellars or basements of buildings. When the danger of flooding is serious, rescue squads in whose districts such possible flood areas exist should be provided with power pumps to empty flooded cellars and basements, in connection with their rescue work, and thus avoid calling upon the fire department in such cases.

A well-organized and directed Rescue and Debris Clearance Service can do much to maintain the normal life of the community in the face of devastating air raids and can also materially reduce the number of casualties that would otherwise occur.

CHAPTER XII

DEMOLITION AND REPAIR SERVICE*

General.—The enormous destructive power of large high explosive bombs creates two special problems to deal with which expert personnel and special equipment are required. The first of these problems is the *removal of large buildings* and structures that have partly collapsed from bomb damage and have blocked streets or otherwise created public obstructions or dangerous hazards. The work of removing these obstructions is essentially an engineering operation, often requiring the skillful use of high explosives and heavy power-driven machinery to loosen and remove parts of buildings still standing. This work is not to be confused with the ordinary clearance of loose debris which is performed by Rescue and Debris Clearance Service parties.

The second problem is the *repair* of vital public service utilities, such as power plants, gas- and waterworks, telephone exchanges, gas, water, and sewer mains, and electric power and telephone conduits, etc. It is obvious that bomb damage to any of these instrumentalities at once deprives the public of some vitally important service in the affected area, and serious consequences may follow unless the damage is quickly repaired and the service restored. Thus, the rupture of a water main not only may deprive the population in the area that it serves of water for all sorts of domestic and business uses but also greatly increases the danger of fire, since water is the only effective means of checking large fires. Again, the breaking of a gas main may cause serious fires and explosions and, in enclosed places, even deaths from asphyxiation. The rupture of a trunk-line telephone cable may completely paralyze communication in the area.

To meet such situations, provisions must be made to

1. Remove promptly any obstruction in streets and public places, no matter how massive and difficult the task.
2. Demolish and clear away heavy damaged buildings and other structures that constitute a public hazard.

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* The information contained in this chapter is based largely upon current British practice and might not necessarily be followed by the United States.

3. Repair and restore to use damaged public service utilities and see that private facilities serving vital public needs are promptly repaired.

In normal times, publicly owned buildings and utilities are maintained in a serviceable condition by the city engineer, and privately owned public service structures and utilities are maintained by the companies that own or operate them. In time of war, however, when cities may be subjected to large-scale air attacks, widespread destruction and dislocation of vital buildings and utilities may occur simultaneously, and it is accordingly necessary to provide special means for dealing with this situation. This is a duty of the Demolition and Repair Service which is a part of the Air Raid Precautions Department (ARPD). It works in closest collaboration with the Rescue and Debris Clearance Service and to a less extent with other emergency services.

As a rule, the Demolition and Repair Service does not move to a scene of damage until the work of the more urgent Air Raid Precautions (ARP) organizations, such as the Fire Precautions, First Aid and Medical, and Decontamination Services, have completed their work. Neither does the Demolition and Repair Service perform any work, such as removing loose debris, that can be done by the Rescue and Debris Clearance Service. On the contrary, it confines its attention to heavy and difficult demolition and clearance jobs that are beyond the capabilities of the Rescue and Debris Clearance Service and to the repair work necessary to restore vital public service utilities to operation.

Organization.—The Demolition and Repair Service consists of a central headquarters, one or more divisional headquarters, and a number of depots from which operate demolition and repair gangs.

The *central headquarters* comprises a Chief of Service, assisted by a technical and administrative staff. The Chief directs the general operation of the Service and is responsible for the recruiting and training of its personnel. He functions under the direct supervision of the Director of Air Raid Precautions and works in close collaboration with the Chief of Rescue and Debris Clearance and other emergency services, as well as with the city engineer and the superintendents of maintenance of the principal public service companies serving the city.

The *division headquarters* comprises a superintendent and staff at the headquarters of each principal subdivision of the city, generally corresponding to an area containing 100,000 inhabitants.

In each divisional area (of 100,000 population), the Demolition and Repair Service maintains a central reserve depot and an average of three repair depots. The central depot is under the control of division headquarters and is used for the training and operation of *demolition and repair gangs* and of reserve personnel for replacing losses.

At the *central reserve depot* are stationed one or more heavy demolition gangs which are called into action only for specially difficult and heavy demolition and clearance work, requiring the employment of large power-driven machinery and frequently involving the use of explosives. A reserve of special equipment and supplies for heavy demolition and clearance work is kept on hand at the central reserve depot which also has normal accommodations for housing and messing the assigned personnel.

Heavy Demolition Gangs.—A heavy demolition gang comprises 1 foreman and about 20 to 30 demolition specialists, such as: steam-shovel engineers, power crane and tractor operators, explosive handlers, riggers, and house wreckers. Where a particular demolition or clearance job may be too large to be handled by one demolition gang, one or more additional gangs may be summoned from adjoining areas, or arrangements may be made with builders and contractors in the city to furnish on call such additional trained demolition personnel and equipment as may be required.

Since it is practically impossible to foresee the extent of heavy structural damage that may be caused by large-scale air raids, it is important to have additional reserve demolition personnel and material available for unforeseen contingencies. Where suitable arrangements may be made with local builders and contractors, this scheme is preferable to maintaining reserve demolition gangs at central depots that may not be required except upon rare occasions.

A *repair depot* is similar to a central reserve depot but is usually on a smaller scale since it does not have to accommodate heavy power-driven machinery and other bulky appliances. It is rather an operating workshop, housing a variety of repairmen skilled in the various building trades, such as pipe fitters, plumbers, heavy metalworkers, welders, joint wipers, cable splicers, conduit repairers, concrete workers, carpenters and joiners, masons, etc.

Each repair depot is in charge of a responsible official and is organized to respond instantly to any calls made on it by the division superintendent or higher authority. Though repair depots do not as a rule respond to calls sent in by members of the public, they are generally authorized to answer a call for assistance from the local Warden, in whose district the depot is located, especially where the repairs required are so urgent that there is not time to secure permission from higher authority.

Repair Gangs.—A repair gang consists of 1 foreman and about 25 special repairmen of the several building trades, as indicated above. As a rule, the repair gang is subdivided into a number of special crews, each expert in a particular type of repair work. Thus, one crew specializes in repair of water mains and sewers; another deals with gas and steam lines; another with electric power cables; and another with telephone lines.

Whenever the repair of a damaged structure or utility requires expertness beyond the capabilities of the ordinary repairmen in the repair gangs, specialists are called in by arrangement with the utility companies whose facilities are damaged. In order to have a sufficient number of expert special repairmen instantly available when needed, arrangements must be made with the utility companies normally employing such personnel to permit them to be enrolled in the Demolition and Repair Service reserve. Such enrollment need not interfere with their daily industrial occupation, except on such occasions as their services may be needed during the workday, in an emergency. It does, however, obligate them to serve as auxiliary repairmen with repair gangs when required. Since damage to vital public service utilities may be very extensive in a large-scale air raid, it is important that the large reserve of expert repairmen be built up prior to the outbreak of an emergency and that the lists be kept revised up to date.

Since repair gangs will work on both publicly and privately owned public service utilities during an emergency, it is desirable that an equitable plan be formulated for prorating the cost of such repair work between the city and the owners of the private utilities. Speed being the prime requisite in such repair work, it is essential that no delays be incurred in efforts to determine who should make the repairs in any particular case. On the contrary, the Chief of the Demolition and Repair Service must be solely responsible and free to take prompt action, no matter whether the damage is to public or private property. When private property is involved, a record is kept of the cost of emergency repair work and charged to the owners of the property in question.

Bomb damage to streets frequently involves injury to the underlying gas and water mains. Thus, a 500-lb. high explosive bomb striking a paved street will penetrate 2 to 3 ft. before exploding and upon explosion will dig a crater 5 to 6 ft. in depth and damage pipes and conduits 8 to 10 ft. below ground. The first step in dealing with ruptured water and gas mains or electric power cables is to cut these services off from the damaged area. This is usually done by Air Raid Wardens, assisted by repair personnel where necessary. If the need for reopening the street is so urgent as to take priority over the repair of the damaged mains or cables, the rescue squads (Rescue and Debris Clearance Service) will effect the necessary arrangements for this purpose. This may involve filling in bomb craters before repairs are made. In the usual case, however, the mains and cables are first repaired by repair gangs and the holes are then filled in by the rescue squads. Later, the paving is repaired by the regular municipal street maintenance department. Because of the joint responsibility, rescue squads, repair gangs, and regular city street maintenance forces must work in close collaboration.

As bomb damage to utilities will greatly exceed ordinary wear and tear, it is important that an adequate reserve of spare parts and repair materials be kept on hand by both the Demolition and Repair Service and the owners of public service utilities. It is a responsibility of the Chief of the Demolition and Repair Service to work out a program for this purpose and see that it is carried out by all concerned. A well-organized and efficiently operated Demolition and Repair Service will go a long way in preventing serious dislocations in the normal life of the community when subject to air attack.

CHAPTER XIII

DECONTAMINATION SERVICE

General.—The deleterious effects of contamination by war gases were indicated in Chap. II, and the general methods of decontamination were discussed in Chap. VI. We shall now consider the *organization* that should be set up, by the civil authorities in each urban community, for the decontamination of streets, buildings, vehicles, and materials generally that have become contaminated with persistent vesicants (*e.g.*, mustard gas and lewisite).

The decontamination organization required in any community will vary according to the density of population and buildings and the degree of contamination to which it is subjected by air raids. In general, congested districts and closely built-up areas will require complete decontamination coverage, whereas suburban and rural areas near cities can be adequately protected by a smaller and simpler decontamination plan in which reliance is placed on mobile units and schemes of mutual assistance between adjacent areas.

Civil authorities charged with the Passive Defense of an urban community will be responsible for decontaminating not only streets and other *public* places, but also adjoining private property where contamination endangers the public safety. The local authorities will also have to undertake the decontamination of private houses and other premises where the occupant cannot reasonably be expected to provide the necessary equipment for himself. On the other hand, large factories, industrial establishments, and other extensive private enterprises will be expected to provide for the decontamination of their own property. Where contamination has been severe and extensive, the local authorities may have to assist private activities in decontamination work; conversely, the latter will help the former where contamination in public areas adjacent private property is so extensive as to exceed the capacity of the local public decontamination personnel.

The same general arrangements will apply to vehicles that have become contaminated. The local authorities will provide facilities for the decontamination of public vehicles and of individual private vehicles that become contaminated at a distance from the owner's garage or where they constitute a public hazard. Otherwise, the decontamination of private vehicles is a responsibility of their owners, as is also the case for public transport companies and large fleets of commercial vehicles. Estimates of public personnel required for the Decontamination Service in any community or area are usually made upon the foregoing basis of responsibility. As the decontamination of streets, buildings, and materials pertains most nearly to the work normally performed by a municipal street cleaning department, the operations of the Decontamination Service are closely associated therewith, and this service may initially draw a large part of its personnel from that source. The Decontamination Service may also be responsible for cleansing contaminated personnel of the Air Raid Precautions (ARP) services and for decontamination of clothing.

Organization.—Since decontamination personnel must work in the closest cooperation with other branches of the ARP service, such as the fire fighting, first aid and rescue services, and the work of these services must frequently be deferred until the work of decontamination is completed, the Decontamination Service is logically a part of the Air Raid Precautions Department and functions under the general supervision of the Director of Air Raid Precautions.

The Decontamination Service consists of a headquarters for each city, a central depot, and a number of operating depots from which decontamination squads operate. It also includes public gas cleansing centers and may supervise or operate one or more large-scale plants for decontaminating clothing.

The headquarters of the Decontamination Service consists of a Chief of Service, assisted by a staff and clerical force. The Chief directs the general operations of the Service and is responsible for the recruiting and training of its personnel. He works in close collaboration with the chiefs of the other ARP services, as well as with the heads of the local municipal police, fire, and street cleaning departments.

The *central depot* is in charge of a superintendent who functions directly under the control of the Chief of the Service and is the place where the main reserves of decontamination workers and equipment are held, ready to be dispatched to any scene of action, as required. It is also used for the training of reserve personnel to augment decontamination forces and replace losses. At least two reserve decontamination squads are maintained at the central depot, so that one may rest while the other is out on call.

A central depot should be conveniently located in the area that it serves and should be easily accessible for motor vehicles by at least two streets, so that it cannot be readily cut off by bomb damage. It should have telephone communication with Service headquarters and the operating depots and should preferably be near a police or fire station through which it could receive messages in the event of a failure of its telephone communication.

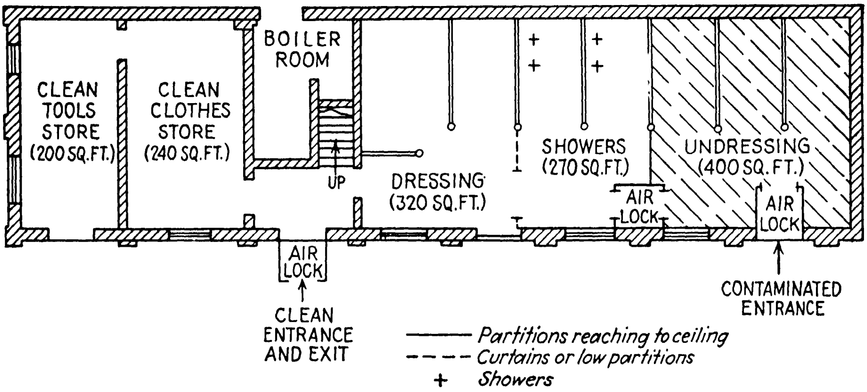

FIG. 35.—Central decontamination depot. (The shading shows compartment in which gas vapor might collect.)

The building housing a central depot should be made gas-proof and splinter-proof, so far as possible, and should have facilities for cleansing contaminated personnel returning from duty, not only of the Decontamination Service, but also for all the other ARP services, except First Aid and Medical Service personnel who are cleansed at first aid stations and hospitals.

The central depot should provide accommodations for housing and messing all decontamination personnel assigned thereto and, in addition, may include accommodations for rescue parties and demolition gangs, if decontamination and rescue depots in the same district are combined. A central decontamination depot should also have facilities for storing and decontaminating equipment and vehicles used by its own and other ARP services. Figure 35 shows a typical layout for a central decontamination depot.

An *operating depot* is a station at which a decontamination squad is based and out of which it operates. The number of operating depots in any area will depend upon the size of the area to be served, the number of decontamination squads in the area, and the percentage of these that are based at the central depot. In densely populated communities, all the squads can be based at one central depot if the area is not too large. In general, if the built-up part of the area is more than 1½ miles from the central depot, one or more operating depots should be established, to avoid delay in dispatching squads. With the usual allotment of six squads to a district having a population of 100,000, a normal arrangement would be to base two squads at the central reserve depot and one each at four operating depots, scattered throughout the district.

An operating depot is organized along the same lines as a central reserve depot, but on a smaller scale, since it usually accommodates but one decontamination squad and has less extensive duties. It should comprise facilities for decontaminating vehicles and household furniture that may be brought in from contaminated premises and should also have arrangements for decontaminating the clothing and equipment of the squad.

Decontamination Squads.—A decontamination squad should consist of 1 foreman and 5 men. A minimum of six squads should be initially organized for every community of 100,000 inhabitants. Cities larger than 100,000 population should be subdivided into operating districts of 100,000 persons each, and each district provided with a district headquarters, a reserve depot, four operating depots, and six decontamination squads. In addition, staffs and working crews are required for each headquarters depot and public gas cleansing center. There should also be a reserve personnel of not less than 25 per cent for the Decontamination Service as a whole, to augment operating squads and crews and to replace losses in all ranks.

The foregoing is a minimum requirement and would not be adequate for the maximum attack that any particular area might receive. The plan of operations for any community should, therefore, include arrangements for concentrating men and materials at the places where attacks with persistent gas have occurred, supplemented by a scheme of mutual assistance between adjacent areas.

The work of decontamination squads is both onerous and hazardous. Working in gas-tight protective clothing is very fatiguing and imposes a heavy strain on the men concerned. They should, therefore, be of good physique and preferably under thirty years of age. As the work of decontamination must be carefully and thoroughly performed in order to be effective, decontamination squads should be carefully trained, both as regards their individual duties and their work as a squad team. Training in methods of decontamination should be given only by qualified instructors who have graduated from a civilian anti-gas school.

The foreman of each squad decides what method of decontamination will be employed in each situation and supervises the work of his squad. When clothed in an anti-gas suit, he should wear a distinctive mark on his sleeve to facilitate his identification.

When an area or building has been contaminated, the decontamination squad should be the first to commence work on the site, so as to avoid casualties among rescue and first aid parties who must follow close behind decontamination squads in their work. All decontamination squads should accordingly be provided with a motor truck having sufficient capacity to move the squad and its equipment, as a unit, quickly to any scene of action in its own or a neighboring district.

Each decontamination squad should be equipped with a supply of several hundred pounds of bleaching powder (chloride of lime) and the equipment required to apply it, in powder or liquid form, to the various kinds of surface to be decontaminated, such as rakes, spades, mops, buckets, etc. One of the most useful devices for applying bleach is a liquid spray and stirrup pump, with sufficient hose to reach from one floor of a building to the next. The squad should also have a supply of decontaminating solvents, such as kerosene and carbon tetrachloride and cotton waste for applying these, as well as a cleansing outfit for scrubbing with soap and water.

The equipment of a squad includes a few hundred feet of rope and a dozen pickets for roping off contaminated areas to exclude the public. It also has a supply of warning signs, 30 by 15 in., lettered "DANGER-GAS" for marking contaminated areas.

Each member of the squad should be equipped with a mask and a complete suit of protective clothing, with at least six extra masks and two spare suits per squad.

For washing off pavements and walls of buildings, each squad should also have at least two lengths of fire hose. A power pump is useful, in case of insufficient pressure in the city water mains. Since fire hydrants may not always be near at hand or may be put out of action by bomb damage, each decontamination squad should have available for use a tank vehicle in which water can be carried or, better still, a regular street-washing vehicle.

Public Gas Cleansing Centers.—As stated in Chap. VI, these centers are provided for the prompt treatment of unwounded members of the public who have become contaminated with vesicant liquids and vapors. They are organized on the scale of one or more for each decontamination district and are operated by the personnel of the Decontamination Service. The exact number of public gas cleansing centers required depends upon the area of the district to be served. Normally, one center per district is sufficient; but if the area of the district is large, one or more additional centers will be necessary, the criterion being that no one should have to travel more than 10 min. to reach a center.

A gas cleansing center should be laid out on the continuous-flow system of handling contaminated personnel. Such personnel are received at one end of the building, passed through a series of rooms where they are cleansed, and then evacuated from the opposite end of the building, means being provided to ensure, throughout the process, that no individual is subject to further contamination. Duplicate facilities, in parallel lines of flow, may be provided, one for men and the other for women and small children; or the latter may be handled in separate centers. Figure 36 shows a typical plan for a gas cleansing center.

In the process of gas cleansing the first essential is the early removal of outer (contaminated) clothing. This step is more safely performed outdoors, or at least in an open weatherproof shed or veranda; hence, the entrance end of a gas cleansing center includes a yard in which shoes are removed and placed in bins provided for the purpose. Any equipment, such as gas masks and steel helmets, are also placed in suitable receptacles in the yard. The next unit of a gas cleansing center is a shed or veranda open to the air on all sides. Here, outer clothing is removed and valuables are placed in specially numbered bags for safekeeping, the owner being given a tally-number receipt for reclaiming same. After removing outer clothing, each individual rubs anti-gas ointment on his hands. On the veranda the heavily contaminated cases are segregated from those lightly contaminated. The first rooms inside the entrance to the building are the undressing rooms, two of which are provided, one for lightly contaminated cases and one for heavily contaminated cases. In these rooms, all underclothing is removed and placed in suitable bins, after which both classes of case pass on into the cleansing room. To prevent spread of contamination between the undressing and cleansing rooms, an air lock is provided and no person is permitted to pass to the cleansing rooms until completely undressed and rid of all clothing.

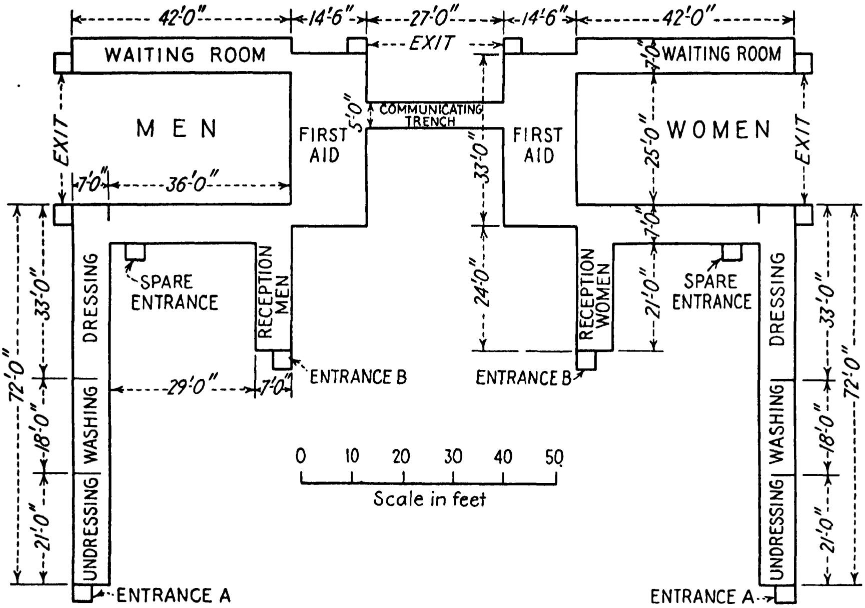

FIG. 36.—Gas cleansing center.

In the cleansing room, two alternative types of treatment are provided. Heavily contaminated cases will bathe in bleach paste, rubbing it well into the skin, and then wash off the paste under a shower, care being taken to prevent the bleach from entering the eyes. If bleach does get into the eyes, it is removed by a cold-water eye douche. Lightly contaminated cases wash thoroughly with soap under a hot shower. A maximum of 2 min. is allowed each man under a shower, to prevent delay in processing.

After washing and drying themselves, all persons pass into the dressing room where they will reclothe themselves with clean clothing issued to them. A clean gas mask, protective clothing, and steel helmet (if required) will also be issued in the dressing room. Finally, all valuables are returned in a room just off the exit to the building, and the completed cases are discharged from the adjacent exit.

When a contaminated person first enters a gas cleansing center, he receives a package of identification tags, having a serial number. He places one of these tags on each article of clothing and equipment which he removes and leaves at the center. When he is ready to leave the center, he signs a memorandum receipt for the government clothes that have been issued to him and receives a receipt, bearing the serial number of his identification tags, for the articles of his personal clothing and equipment that he leaves behind. His receipt informs him where and when to call for his personal property after it has been decontaminated. When he presents himself at the decontamination center to reclaim his property, he turns in the government clothing and equipment that has been loaned to him, and receives his own clothing and equipment in return. The government clothing and equipment are then cleaned and sent back to the gas cleansing station to be used again.

A building used as a gas cleansing center should be splinter- and gas-proof and provided at its entrance and exit with suitable gas-tight air locks. The yard at the entrance end of the building is enclosed by wire-mesh fence and is divided into areas for the depositing of equipment and shoes by a low wire-mesh fence about 2½ ft. high.

The interior walls and floors of the building should be made of nonabsorbent material, such as specially finished concrete and glazed tile, which does not readily adsorb vesicant gas and is easily decontaminated. The undressing and washing rooms are provided with gutters and sumps for rapidly draining off contaminated water, and a long cement trough or baths are installed in the cleansing room for bleach treatment. Tables and chairs should be covered with oilcloth or other nonadsorbent material. Notices should be posted giving instructions at each stage of the process to prevent confusion.

Vehicle Decontamination Depots.—In addition to facilities at decontamination depots for decontaminating the vehicles used by the ARP services and such other vehicles as may be brought in from contaminated premises, it is necessary to provide one or more public depots for decontaminating vehicles that have been contaminated in the streets. Such a depot comprises a yard large enough to accommodate contaminated vehicles without causing danger or inconvenience to neighboring premises and a number of concrete wash racks. The process of decontamination involves the application of decontaminating agents and a copious supply of water. Each wash rack should, therefore, be equipped with a hose, water supply, and ample drains for carrying off contaminated water. The wash racks should be made of specially treated concrete or other material having an impermeable surface to resist contamination.

The necessary decontaminating materials and hose will be supplied by the depot; but the drivers of the contaminated vehicles will perform the work of decontamination, under the direction of a foreman in charge of the depot. Where the work of decontamination is too great to be performed with sufficient dispatch by the vehicle drivers, the depot will furnish additional personnel to assist.

Public transportation establishments, such as railroads, bus lines, trucking companies, and barge lines, having large complements of rolling stock or barges, will maintain and operate their own vehicle decontamination depots.

Decontamination of Clothing.—The decontamination of clothing used by the ARP services and that removed from members of the public at gas cleansing stations is a responsibility of the Decontamination Service. One method of accomplishing this task is to send all contaminated clothing in each district to a commercial steam laundry designated by the local authorities for this purpose. The work of decontaminating clothing can be satisfactorily performed in such laundries if they are properly equipped for this purpose and the process is supervised by a qualified foreman. Special arrangements for handling decontaminated clothing at commercial laundries, on a piecework or flat-rate basis, are made by the Chief of Decontamination Service in each city.

An alternative arrangement for decontaminating clothing, especially applicable in large congested districts, is for the Decontamination Service to take over one or more large commercial steam laundries and operate them as decontamination plants, with its own personnel. The particular arrangement to be adopted for each district will depend primarily upon the volume of clothing to be processed.

In any case, the chief of decontamination work in each district will arrange an organization for the collection of all contaminated clothing in his district and for its dispatch to such laundries as may be designated by the authorities. He will also arrange for the return of cleansed clothing from the laundries, for its distribution to the owners, and for the maintenance of the necessary records and registers pertaining to such clothing.

Another duty of the Decontamination Service is the maintenance of a suitable working stock and reserve of clean clothing at all first aid posts, decontamination depots, and public gas cleansing stations, for issue to contaminated personnel after cleansing. To members of the public, this clothing is issued as a loan during such time as their own clothing is being decontaminated. The quantities of such clean clothing to be kept on hand at any establishment will vary from 10 to 1 per cent of the total persons to be served, the former percentage applying to small stations, serving 500 persons, and the latter to large stations, serving over 30,000 persons.

Areas outside Cities.—The Decontamination Service described above applies only to large urban communities. For areas outside cities, less elaborate plans for decontamination will suffice. Each local community should have its own plan for decontamination, but such plans should be coordinated by the county authorities and should be based upon the principle of mutual assistance between neighboring localities.

GAS DETECTION AND IDENTIFICATION SERVICE

General.—Since the identification of known war gases and the detection of new gases will frequently require the services of technical experts who not only are graduate chemists but have been specially trained for this work, it is necessary to set up a special organization for this purpose, known as the Gas Identification Service.

In addition to the detection and identification of gases, this Service determines the extent of contamination of gassed areas and the duration of the danger; it also advises the local authorities on any problem of contamination and on technical questions arising in connection with the organization and operation of the anti-gas services in the localities for which they act. It is not a duty of the Gas Identification Service to *order* the decontamination or clearance of inhabitants from infected areas or to *supervise* such work.

Though not a part of the Decontamination Service, the Gas Identification Service works in the closest association therewith; and, for that reason, the subject is included in this chapter.

Organization.—The Gas Identification Service consists of a Chief of Service for each state and a *Senior* Gas Identification Officer (G.I.O.) and two Assistants for each urban community of 100,000 population. For cities larger than 100,000, an extra Assistant is added for each 33,000 additional population, and one additional Senior Officer for each 100,000 population. For cities of more than 300,000, a *Chief* Gas Identification Officer is provided to supervise and coordinate the work of this Service throughout the city. The foregoing ratio will permit the assignment of one Gas Identification Officer, or Assistant, to each Senior Warden's area (1 square mile), and one Senior Gas Identification Officer in each Principal Warden's area, as defined in Chap. VIII.

The *Chief of Gas Identification Service* is a specialist on the staff of the State Director of ARP. He should be chosen for exceptional chemical qualifications and will be the normal channel of communication on anti-gas protection matters between the Gas Identification Service of the local authorities in the state and the department of the Federal Government charged with the Civil Air Defense of the country. His services will be available, in an advisory capacity, to the local authorities in his state; but he will not form a part of a local authority's organization and will not be concerned in recruitment, conditions of service, or equipment of local services.

The Chief of Gas Identification Service should have available, either at his home station or in the largest city in his state, a well-equipped laboratory for the analysis and identification of war gases. In cases where local gas identification officers cannot determine the identity of any gas used by hostile aircraft against a community, they will send samples of contaminated earth or other articles to the state laboratory for analysis and determination.

The *Gas Identification Officers* form a part of the local ARP service in each community and are selected from among persons of suitable professional qualifications, not liable for military service. After receiving special training for their work, they act in an advisory capacity as professional gas identification consultants. As they have the status of expert advisers and are not clothed with any executive authority, it is not a part of their duty to order or supervise decontamination work, or clearance of inhabitants from infected areas, etc.

Gas Identification Depots.—In each city, there should be one central gas identification depot and as many operating depots as there are gas identification districts (*i.e.*, G.I.O.'s). The central depot should contain a small chemical laboratory capable of making rapid and simple analyses and identifications, and all depots should have gas cleansing and decontamination facilities. As a rule, the simplest arrangement is to make each gas identification depot a part of the decontamination depot in that area (see page 224). This ensures adequate gas cleansing and decontamination facilities and operating personnel without duplication of installations.

Operation of Gas Identification Service.—Since Air Raid Wardens, police, and decontamination squads will ordinarily be the first personnel to reach a contaminated area, it is the duty of such personnel, in the absence of the Gas Identification Officer, to determine by the best means available the presence and extent of contamination. If they have reason to believe that gas is present, Wardens will warn the public and give immediate information to the report center (see Chap. XIV), which will notify the Gas Identification Officers and arrange for the dispatch of decontamination squads to the infected area, if none are already on hand.

Ordinarily, Gas Identification Officers and their assistants will reside in the district they serve and will not be required to leave their homes or places of business until they are notified by the report center that a gas attack has taken place. When such notice is received, the Gas Identification Officer will proceed to the spot and determine whether or not gas is present and, if so, its nature and the extent of contamination. He reports this information to the report center and advises the services operating on the spot as to the extent and duration of the danger.

After a tour of duty, the Gas Identification Officer or assistant will proceed, if necessary, to the depot in his district for the purpose of cleansing and decontaminating himself and his special apparatus. He then puts on a clean suit of clothes that is always kept available for him at the depot.

In addition to the duties mentioned above, Gas Identification Officers will also be available to advise the local authorities on any decontamination or anti-gas problem.

Equipment of Gas Identification Officers.—Each Gas Identification Officer and assistant will be equipped with the following:

1. A portable kit containing gas detecting and sampling equipment.
2. Complete anti-gas suit and mask.
3. Pair of manipulative rubber gloves.
4. Steel helmet and flashlight.
5. Notebook and report forms.
6. Motor transportation.

Training of Gas Identification Officers.—Each Gas Identification Officer will be given local preliminary training in anti-gas and decontamination work and in the local ARP organization. They are then sent to a central ARP school and given a special course in the practical methods of gas detection and identification of war gases under simulated air raid conditions.

CHAPTER XIV

AIR RAID PRECAUTIONS COMMAND ORGANIZATION*

General.—In Chaps. VII to XIII, we have described the various services that perform the several functions of Passive Defense and constitute the Air Raid Precautions Department (ARPD). We shall now consider the means and methods of supervising and controlling the operations of the ARPD as a whole, so that the various services function in a coordinated manner and work together as a team. Supervision, control, and coordination constitute the three principal elements of command, and the mechanism for performing these functions may be termed the *Command Organization.* In the case of the Air Raid Precautions (ARP) services of a large community, the Command Organization comprises

1. A *General Headquarters* of the ARPD for the whole community.
2. A *division headquarters* for each major subdivision of the community, generally an area of approximately 3 square miles, containing a population of about 100,000, and corresponding to a Principal Warden's division (see Chap. VIII).
3. A *main report center* for the whole community where all division reports of air raid damage are collected and consolidated into permanent records, for administrative and statistical purposes.
4. A *division report center* for each division headquarters, as defined in (2) above, where reports for each major subdivision of the community are collected for action by division headquarters.
5. A *local report center* for each square mile containing a population of about 33,000 (*i.e.*, corresponding to a Senior Warden's group) where reports of air raid damage are submitted by Wardens, police, and other members of the ARPD for the information and action of the controlling officials.
6. A *communications network,* whereby:

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* The information contained in this chapter is based largely upon current European practice and might not necessarily be followed by the United States.

a. Information concerning the fall of bombs, and the damage caused thereby, may reach the ARP services concerned, with the minimum delay.

b. The several headquarters, report centers, and local units of the various services, may receive calls for aid and dispatch assistance.

c. The various activities within each service, the several services, and the ARPD authorities in adjoining areas, may communicate with each other.

It is essential that each headquarters should be aware of, and in a position to control, the main movements of the component parts of the ARPD as the general situation in its area may require. The cardinal principle of operation of the Passive Defense system as a whole should be *centralization of control and decentralization of operation.* In theory, this control should be complete; but, in practice, latitude must be allowed subordinate units according to the extent and character of the area in which they operate and the nature of the service. The system must also provide for the independent action of subordinate parts of the organization when contact is lost with higher headquarters.

The command organization should therefore be flexible, and each local authority must consider within the general framework what particular scheme is best suited to the needs of its community. In small towns and rural areas, the command organization may be very simple, and existing facilities will probably suffice, if properly organized for this purpose. In larger towns and cities, a higher degree of organization is required; hence, the command mechanism must be more elaborate, and the existing facilities will generally have to be supplemented.

General Headquarters.—The size and complexity of the General Headquarters of the ARPD in any community will depend largely upon the magnitude of the community. For a small city (*i.e.*, about 100,000 population) a division headquarters, as described below, is all that is required. For each increment of 100,000 inhabitants, an additional division headquarters will be needed; and where two or more division headquarters are in operation, a General Headquarters is necessary to supervise and coordinate their activities and those of the several services, for the community as a whole.

For very large cities (*i.e.*, over 1,000,000 population) the number of division headquarters is considerable, and the size and complexity of the several ARP services is such as to require a well-organized and elaborated General Headquarters properly to supervise, control, and coordinate their work. It is also probable that in cities of 1,000,000 or more population, it will be found advantageous to group each three or four adjoining division areas under an intermediate Zone Headquarters, in order to secure better coordination and control. This is, however, a matter that can best be determined by the local authorities in each large city.

Organization of General Headquarters.—The General Headquarters of a large urban ARPD consists essentially of the following:

1. A Director of Air Raid Precautions.
2. A Deputy Director.
    a. An Assistant Director for Personnel and Administration.
    b. An Assistant Director for Intelligence and Public Relations.
    c. An Assistant Director for Training and Operations.
    d. An Assistant Director for Supply, Construction and Transportation.
3. A Chief of Air Raid Warden Service, and Assistants (Chap. VIII).
4. A Chief of First Aid and Medical Service, and Assistants (Chap. IX).
5. A Chief of Fire Precautions Service, and Assistants (Chap. X).
6. A Chief of Rescue and Debris Clearance Service, and Assistants (Chap. XI).
7. A Chief of Demolition and Repair Service, and Assistants (Chap. XII).
8. A Chief of Decontamination Service, and Assistants (Chap. XIII).
9. A Chief of Gas Identification Service, and Assistants (Chap. XIII).
10. A Chief of Communications and Alarms, and Assistants (Chap. XIV).
11. A clerical staff and office assistants, including telephone operators, messengers, guards, janitors, etc. (see Figure 37).

The *Director* supervises and controls the work of the ARPD throughout the city and reports to the Director of Civil Air Defense who is responsible for the defense of the community against air attack and should be subordinate only to the mayor.

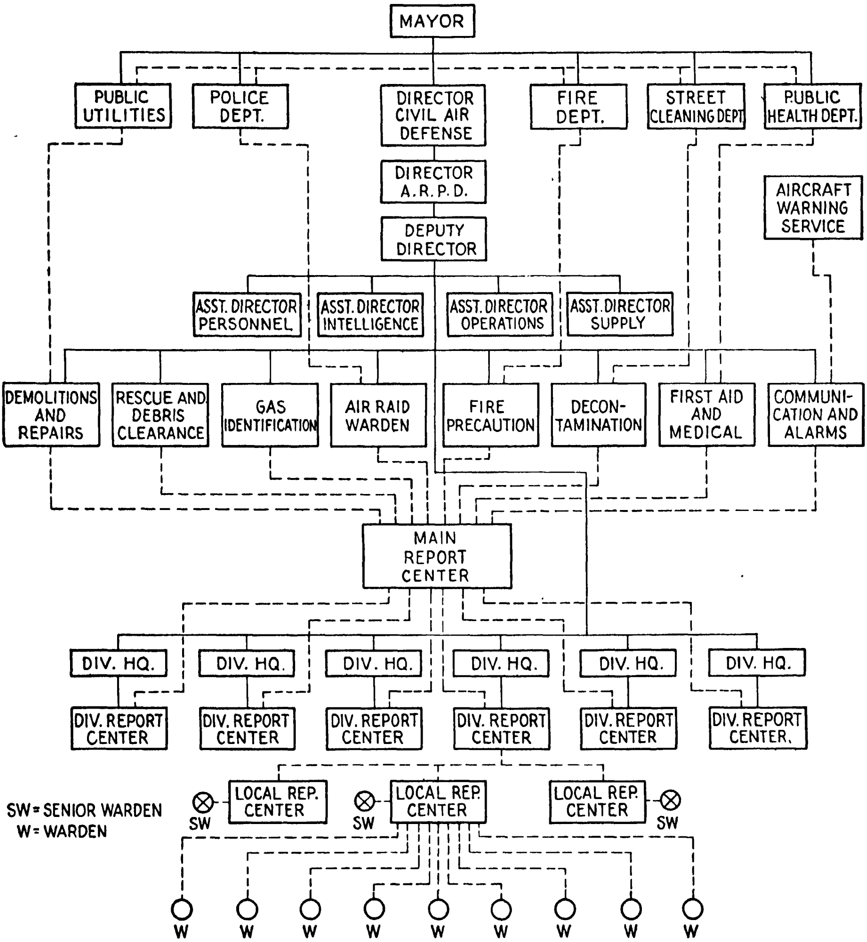

FIG. 37.—Organization chart. Air Raid Precautions Department for a large city.

The Director of ARP works in close cooperation with the chief of police, chief of the fire department, and other heads of the regular city government agencies and maintains contact with the State Director of ARP of his state.

The *Deputy Director* functions as the Director's Chief of Staff and, as such, supervises and coordinates the work of the General

Headquarters staff and the operation of the ARPD as a whole. The *Assistant Directors* aid the Director in their respective functions, as indicated above.

The *Chiefs of the several services* supervise and control the operation of their respective services throughout the city and act in an advisory capacity to the Director of ARP in all matters pertaining to their jurisdictions. Each Chief of Service is also responsible for the recruitment, training, and equipment of the personnel of his service.

The *Chief of Communications and Alarms* is responsible for seeing that the communications network between all elements of the ARPD is properly maintained and operated by the telephone company in accordance with prearranged plans of communication, with first priority to ARPD telephone traffic during air raids. He accordingly works in close collaboration with the district telephone manager. He is also charged with the installation, operation, and maintenance of the local system of air raid alarms and signals (see Fig. 37).

The General Headquarters of the ARPD should preferably be housed in one building, for convenience of operation and maintenance of close contact between the heads of the various sections and services. This building should also be conveniently located with reference to the city hall and other buildings accommodating the several departments of the permanent city government. It should have adequate telephone lines to the city hall, its division headquarters, and the various report centers, with a private branch exchange having lines to at least two public exchanges.

Organization of Division Headquarters.—A division headquarters of the ARPD consists essentially of the following:

1. A Superintendent of Division.
2. An Assistant Superintendent.
3. A Supervisor of each ARP service.
4. A clerical staff and office assistants, including telephone operators, messengers, guards, janitors, etc.

The Superintendent has general charge of the work of all ARP services in his area and coordinates the activities of these services therein. The Assistant Superintendent aids the Superintendent in his functions, performs such special duties as may be assigned to him, and acts as Superintendent in the absence or disability of the latter. The Supervisors of the several services control the operation of their respective services in the area and maintain contact with their chiefs of service.

The Division Headquarters is a channel of communication for reports of an administrative or statistical nature from report centers to General Headquarters, but not for routine calls for assistance in emergencies. Each division headquarters should be tied in the communications net with: (1) all report centers and other ARPD activities in its area; (2) regular city police and fire stations in its area; and (3) General Headquarters. It should be housed in one building, conveniently located near the center of its area.

One of the principal duties of a division headquarters is to endeavor to handle all emergencies due to air raid damage in its area without calling on General Headquarters for assistance. It should mobilize the resources of all the services and districts in its area and see that they are utilized to the maximum extent practicable, before calling on higher authority for help in emergencies. Whenever it appears that an emergency cannot be met by the resources at its command, the Division Headquarters should report the situation to General Headquarters and request specific aid in each case.

Main Report Center.—In every large city subject to air attack, there should be a main report center where incoming reports of air raid damage are received and passed on to the controlling officials of each service at General Headquarters. Messages *within one service,* as from a subordinate to his Chief of Service, would pass direct and not through the Main Report Center (see Fig. 38).

Since incoming reports of air raid events generally affect more than one service, they are usually taken down in writing at the Main Report Center and relayed either by telephone or messenger to the interested services. The General Headquarters as a whole, and the chief of each service in particular, rely upon the Main Report Center for general information. The center should, therefore, automatically report to all services concerned any matter that may affect that service, such as the fact that certain roads are blocked, bridges destroyed, or areas closed by contamination.

It is important that the Main Report Center be kept constantly supplied with up-to-date information concerning the air raid situation throughout the city. This is accomplished principally by routine reports from division report centers where they exist, otherwise by reports from local report centers or, in some cases, by direct reports from members of the ARP services.

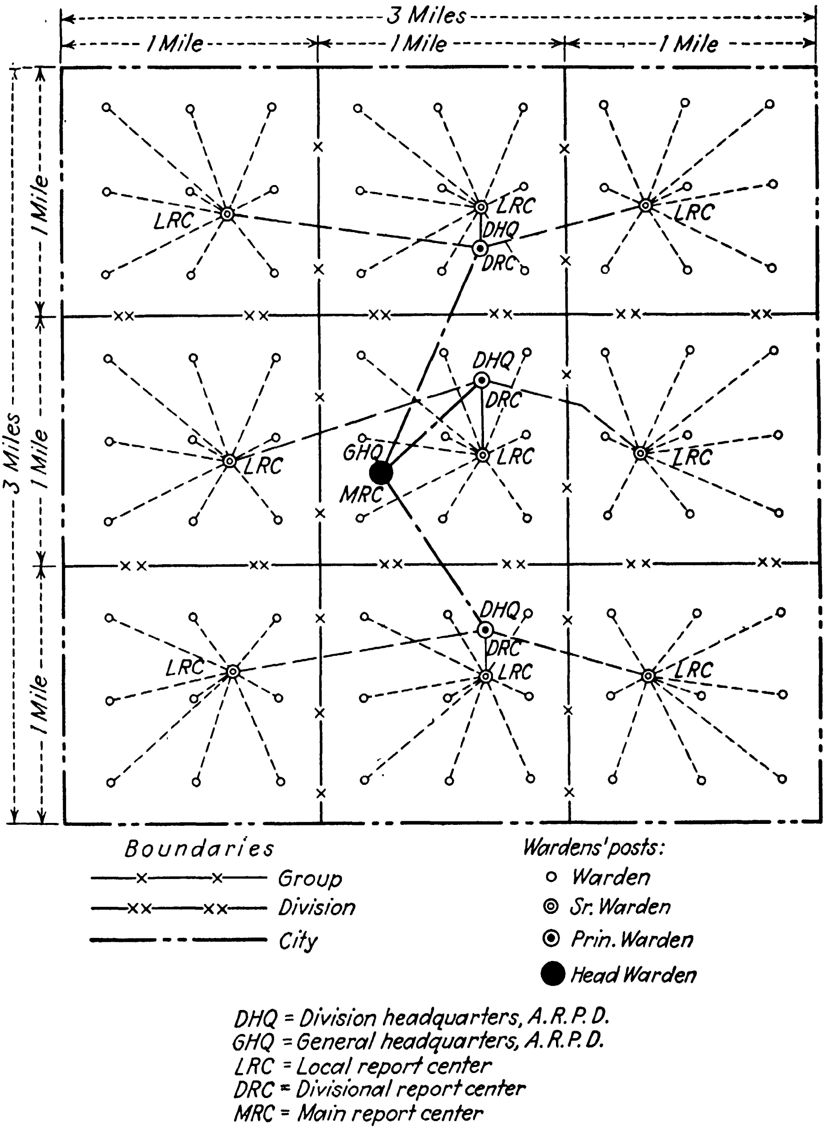

FIG. 38.—Scheme of organization. Air Raid Precautions Department for city of 300,000.

The *organization* of a main report center comprises three principal parts: a telephone switchboard with at least 12 lines interconnected to not less than three public telephone exchanges; a room for receiving and transmitting messages; and a large-scale map of the city on which the location and nature of air raid damage can be marked.

If the telephone lines to the report center are connected to an existing branch exchange, a special switchboard is unnecessary. The switchboard should have two operators and should be located in as safe a place as possible, preferably in a splinter-proof basement. The number of telephone extensions to the message room should be sufficient to handle simultaneously the volume of incoming and outgoing traffic through both the exchange lines and the switchboard extensions.

The message room is arranged with a row of telephone desks or booths on each side, so that incoming messages are handled on one side of the room and outgoing messages on the other. A table in the center of the room is arranged for the sorting and temporary filing of incoming and outgoing messages.

When in operation, the message room should be occupied only by the report center staff. For this reason, a separate room should be provided for messengers; clerks and the operation map should also be located in another room.

The operation map of the city should be on a scale of at least 6 in. to the mile in the urban areas and should have marked upon it the boundaries of the subdivisions of the city served by the regular police and fire departments and the several ARP services. On the map, the various ARPD depots, report centers, etc., should be shown, and also the locations of all facilities of the public utilities services, such as water, sewer, and gas mains and electric power and telephone conduits. To facilitate the finding of locations on the map, it should have a superimposed grid of Cartesian coordinates 2 in. apart, with the ordinates numbered from left to right and the abscissas lettered from bottom to top.

The *personnel of a main report center* should comprise two complete staffs, to work in reliefs, each consisting of the following:

1 Controller in charge
1 Assistant Controller (for relief)
1 message dispatcher
1 assistant message dispatcher (for relief)
2 plotters
2 switchboard operators
12 telephone clerks and typists (6 for receiving and recording incoming messages and 6 for dispatching outgoing messages)
2 file clerks and typists
2 statistical report clerks
2 messengers (indoor)
24 Total for one shift

Additional messengers will be also required to carry messages outdoors if the telephone system fails.

The *Controller* is the officer in charge of the report center. Upon him depends the operation of the whole system, for he decides what action is to be taken on each incoming message, what services are to be informed, and the order of priority. His task requires intelligence, keenness, and coolness; if he does not possess the necessary qualifications, the whole system will break down.

The *message dispatchers* are also keymen. They must see that all incoming messages are properly recorded and all outgoing messages are dispatched in order of priority. They must also know all the alternative methods of delivering messages to their destination.

The *plotters* must have an accurate and detailed knowledge of the city, and particularly its public utility system, the regular police and fire departments, and the ARPD organization.

The *clerks* who man the receiving and dispatching telephones must be coolheaded and trained for the work, and the rest of the staff must be accustomed to handling messages and reports.

Since a report center that is used for the reception and relaying of messages may easily become congested, it is very important that a simple fixed routine be adopted in time of peace for the operation of the center. This routine should be standardized throughout the ARPD control system and should include the maximum use of standard forms for reports and messages, etc. The personnel of a report center should be capable of sorting out and collating a mass of information, much of which will be in an undigested form and on some of which it will be necessary to obtain confirmation.

The Main Report Center should keep a record of all messages, received and dispatched, and of the action taken thereon. It should be prepared to provide periodic estimates of the situation in any part of the city, based upon reports received and confirmed. It is equally important that any unconfirmed information that appears to be unreliable should be clearly indicated as such. Periodic tests of the operation of the Main Report Center should be conducted for practice in time of peace.

The *routine for handling the message traffic* in a main report center is as follows:

All messages are taken down by a telephone clerk in a standard message form book which is provided with a carbon sheet for making duplicates. One (file) copy remains in the message book, and the other is passed to the plotter who numbers the message form and marks up the map as required.

In plotting the data on the map, the plotter inserts a colored pin, with an "occurrence" number, at the position in question and marks on the message form the reference number of the occurrence. The colors of the pins show the type of bomb; *e.g.*, black means high explosive; red means incendiary; yellow means gas.

The plotter then hands the message to the controller who decides what "action" is required and indicates what services are to be informed and in what order of priority.

The message is then passed to the dispatcher who is responsible for seeing that all necessary action is taken as directed and by the best means available.

When *action* is completed, the message form is handed to the file clerk who enters the necessary data on a daily journal form and then files the report in the proper file.

Division Report Center.—A division report center is similar to the Main Report Center in function, organization, and operation, the only essential difference being the smaller area covered. A division report center should be located adjoining, or as close as possible to, the Division Headquarters and has the same relation thereto as the Main Report Center has to the General Headquarters. It should have at least eight telephone lines to one or more public exchanges and extensions to the various sections of the Division Headquarters (see Fig. 36).

The only difference in organization between the Main Report Center and a division report center is in the somewhat reduced personnel of the latter. Thus, a division report center needs only the following personnel for one shift:

1 Controller in charge
1 Assistant Controller (for relief)
1 message dispatcher
1 assistant dispatcher (for relief)
1 plotter
1 switchboard operator
8 telephone clerks and typists
1 file clerk and typist
1 statistical clerk and typist
1 messenger (indoor)
15 Total for one shift

A division report center operates in a manner identical to that of a Main Report Center, except that it covers a limited area and accordingly handles a smaller volume of business.

Local Report Center.—This center is the same in function, organization, and operation as a division report center, except that it covers a smaller area and handles a smaller volume of business. It needs only four telephone lines to a public exchange and therefore requires only four telephone operators per shift, instead of eight.

There being no ARPD operating headquarters corresponding to a local report center, the latter normally transmits its messages to the Division Report Center and occasionally (as when direct lines are out) to the Main Report Center for necessary action. The Local Report Center should keep the Senior Warden of the area informed of the air raid situation therein and should assist him in summoning local aid, when such action is required (see Fig. 37).

Method of Control.—In each Senior Warden's group area the several ARP services maintain a central depot and several operating depots which are subject to call for assistance in an emergency by the Controller of the Local Report Center in the area. An operating depot is also subject to direct call by a Warden in whose district it is located; but a central depot is not subject to direct call by the local Warden, but only by the Controller of the Local Report Center.

When an emergency is so serious that it cannot be handled by the ARPD facilities in a group area, the Local Report Center calls through its Division Report Center upon the Division Headquarters for aid, whereupon the division Superintendent may call out any of the ARPD facilities in his area (corresponding to a Principal Warden's division).

Similarly, if the emergency is such that it cannot be handled by the ARPD facilities under the control of a division headquarters, the division Superintendent calls through the main message center upon the General Headquarters for assistance, whereupon the Chiefs of the ARPD services call out such of their facilities (anywhere in the city) as they deem necessary to meet the situation (see Fig. 37).

Form of Report.—Wardens and other reporting agents of the ARPD should be trained to use standard forms in reporting air raid casualties and damage. This not only saves time but eliminates duplication of work and confusion. Code messages should not be used, for they impose an added responsibility and complication in time of stress and really serve no useful purpose. Likewise, the receipt of messages at report centers and depots of services should be recorded on standard forms.

The sending out and returning of parties, other action taken, and work performed should be reported by the various depots to the headquarters of its service, which should then inform the division report center of the completion of its work at the scene of damage and of important occurrences affecting the general situation. Periodically, each division report center furnishes the main report center with a summary report showing all air raid events and results of bomb damage occurring in its area within the period covered by the report, the action taken thereon, and the work accomplished.

The public should be advised not to use the telephone to seek aid during air raids, except where no other means of communication is available; for this practice will congest the telephone lines to the various report centers and depots and thus hamper, rather than help, the work of the ARP services. The public should be told to communicate its needs through local Air Raid Wardens, patrolling police officers, and other members of the ARPD who are at hand, and to use the telephone only when no other means of securing help is available.

Communications.—In the operation of the ARPD, the principal means of communication is the public telephone system, and the supplementary means are (1) the regular city police and fire call systems; (2) two-way short-wave radio between ARPD report centers, depots, and operating parties; and (3) messengers.

The use of the *public telephone system* for ARPD purposes in time of emergency requires a carefully worked-out plan embracing the following provisions:

1. Full use of the existing telephone facilities, including private branch exchanges.
2. The reserving of certain trunk lines between important ARPD report centers, depots, etc., exclusively for the use of ARPD business during air raids.
3. Priority of service for ARPD business on other lines during air raids.
4. Restriction of the use of telephones by the general public during air raids, to the maximum extent practicable, in districts in which bombs are falling.
5. The assignment of ex-directory numbers to important ARPD stations, which numbers would be known only to ARPD officials.
6. Arrangements for making repairs to telephone lines damaged by bombs with the minimum delay, including the use of special mobile emergency repair gangs.

7. Arrangements for shunting ARPD telephone calls over alternative lines, where main lines are damaged, and the interconnection of all city exchanges to facilitate this work.

8. Arrangements for quickly installing additional lines to ARPD stations where lines originally allocated prove inadequate.

9. Arrangements for the use of telephones in buildings adjoining those used for ARPD activities, in case regular lines go out of action.

The ARPD plan for using the public telephone system, including the foregoing measures, should be formulated in time of peace by the Chief of Communications and Alarms in collaboration with the city telephone company officials.

The *city police and fire call systems* may frequently be used to advantage as auxiliary means of communication between ARPD message centers, depots, and field agencies, if their central stations are tied into the ARPD communications network. The police and fire call lines are of special value to Wardens, mobile fire patrols, and other ARP work parties, in affording them a ready means of communicating with their report centers and depots when city telephones are not available.

Short-wave radio may also be used to advantage between ARPD report centers and depots and Wardens, fire patrols, and other ARP mobile units. For this purpose, each report center and depot and each mobile unit is equipped with a two-way short-wave radio set, and the system of communication is similar to that employed by the regular police patrols. The ARPD radio system should be tied in with the regular city police radio system, so that the two supplement and do not interfere with each other.

Finally, a *system of messengers* should be provided for use in case of a breakdown in the telephone service. Three types of messenger should be utilized: (1) motorcycle men, where the streets are reasonably clear; (2) bicycle men, where the roads are obstructed in places by bomb craters or debris; and (3) runners, where neither motorcycles nor bicycles can be used.

In principle, each ARP service should be provided with its own corps of messengers for delivery and bringing in messages from report centers, depots, or other local activities.

Air Raid Warnings.—The communication system described above may also be used for distributing air raid warnings within the city, but a special organization is required for this purpose (see Chap. VIII).

Command Organization in Smaller Cities.—In cities with less than 300,000 population, it is probable that a somewhat simpler organization for Civil Air Defense will suffice. The functions of the several ARP services could be performed by the regular city government departments, with the addition of the necessary personnel for this purpose. Thus, Air Raid Wardens could function under the city police department; the emergency fire-fighting forces, under the city fire department; and the Decontamination Service, under the city street cleaning department, etc. In this way, the ARP service functions can be carried on without creating a separate ARPD. However, it will still be necessary to appoint a Director of ARP to plan, supervise, and coordinate ARP work throughout the city and to furnish him with a small technical and administrative office staff to assist him in carrying out his duties (see Fig. 37). But this is a very much simpler organization than that required for a large city, as described above.

Command Organization in Rural Areas.—In areas outside cities and towns, the command organization for controlling ARP activities can be greatly simplified. In each village a very simple report center can be set up near the local telephone exchange and arrangements made to have the exchange operators switch calls for aid direct to whatever ARP facilities are locally available.

The report center itself may be quite simple. It would be required to function only when a raid was in progress and for the danger period after the fall of bombs. It could consist merely of a few extra men, added to the local civil authorities headquarters, for the purpose of coordinating the use of local facilities for Civil Air Defense purposes. Unlike the situation in urban areas, in rural areas the maximum use should be made of householders and members of the public for sending in information concerning the fall of bombs and the resulting damage and in requesting aid in emergencies.

Like other ARPD activities, the command organization in rural areas should be predicated upon the principle of mutual assistance among neighboring communities and should be coordinated by an ARPD official for the whole county. This official should be on the staff of the county sheriff or other officer responsible for county government.

CHAPTER XV

TRAINING OF AIR RAID PRECAUTIONS PERSONNEL*

General.—No matter how complete the Air Raid Precautions (ARP) organization in any community, the ARP services will not be able to operate effectively unless their personnel have received proper training, first as individuals, then as members of teams and work parties, and finally in collaboration with other branches of the Air Raid Precautions Department (ARPD).

The success of the ARPD in protecting the civil population and enabling it to resist the destructive effects of air raids will depend largely upon the behavior and competence of ARP workers in an emergency. To ensure that ARP personnel of all ranks will perform their work in an orderly and efficient manner when called out during air raids demands a high standard of training and morale. Accordingly, the objective of all ARP training should be to obtain the highest working efficiency, good will, loyalty, discipline, and team spirit among all workers.

In general, the Chiefs of the various ARP services are responsible for the training of the personnel in their respective branches; but there is a certain amount of common basic training, as well as combined and higher staff training, that should be dealt with centrally under the authority of the Director of ARP.

To assist him in the performance of his training responsibilities, the Director of ARP has on his staff an Assistant Director for Training and Operations who, among other duties, is charged with the following:

1. General supervision of the training of ARP personnel.
2. Coordination of training among the several ARP services.
3. The general direction of central ARP schools.
4. The supervision of ARP instructors, combined training, and higher staff training.
5. Arrangements for refresher courses for ARP instructors.
6. Coordination of training of ARP personnel in industrial and commercial establishments.

***This chapter is based on current British practice.**

General Training Plan.—Since the training needs of members of the ARP services will vary widely between those newly enrolled and those with previous training and experience, the general training plan for ARP personnel should comprise a number of stages which are taken progressively, the sequence being arranged to cover a complete scheme of training from the new recruit to the staff specialist. The plan should also be flexible so that any stage can be used alone and so that the sequence can be made to start with any stage.

A general training plan, embodying these principles, should comprise the following training phases:

1. *Individual training*, which consists of two parts: basic and advanced.

Basic training comprises *elementary* training in the following subjects, *common* to all branches of the ARPD:

a. Organization for Civil Air Defense.
b. Protection against high explosive bombs.
c. Protection against incendiary bombs.
d. Protection against gas.
e. First aid treatment.

Advanced training comprises further instruction in the foregoing subjects, in order to raise the standard of knowledge acquired; and *technical* training in the *work* of the *Service* in which the trainee is enrolled.

2. *Team training*, which consists in the training of individual workers as members of a team and the practicing together of teams of the same service.

3. *Combined training*, which consists in the cooperative training of the different ARP services by means of combined exercises.

4. *Higher staff training*, which consists in exercises in the handling of the larger problems in air raid protection, the reinforcement of one area from another, and the conduct of large-scale exercise.

In addition to the foregoing, the general training plan should also include:

1. Instructions for the organization of training at ARP posts, depots, and centers, including the establishment of a regular and ordered routine of daily life of ARP workers when on duty.

2. Provisions for training *part-time* personnel so that, within the time they are available, they may quickly reach the same standards of proficiency as full-time personnel.

The training in each community and area is conducted in accordance with applicable portions of the general training plan. Instructors are assigned to give definite courses, and the times and dates of each course are fixed, after consultation with the Chiefs of Services concerned, so that those requiring any particular course will be able to attend. The times of commencement of similar courses is staggered so that a trainee who is unable to attend for a particular lesson at the scheduled time will have other opportunities of attending that lesson when it is being given in another course. This is particularly beneficial for part-time enrollees.

Since basic individual training for all branches of the ARPD is the same, it will generally be found more economical and efficient to pool instructors and conduct this training with combined classes in one place in each community or area. It is also advantageous if one instructor can conduct a course from beginning to end.

General Training Program.—In order that all ARP personnel will receive the training prescribed for them in the general training plan, a general training program is formulated. This program shows in detail the courses of instruction given enrollees in each ARP service and the approximate number of hours devoted to each course. Table IV shows a typical general training program for the ARP services.

Local Training Plan.—In each local community and in each large city area containing 100,000 people, there should be formulated a local training plan, based on the general training plan and program described above, for the individual, team, and combined training of ARP enrollees.

Except for the Air Raid Warden Service, the majority of the local training is carried out at the central depots of the several services in each community and area. In the Warden Service, the greater part of local training is performed at the District Wardens' posts. As it is extremely difficult to secure satisfactory training results, unless regular and orderly attendance of trainees at the prescribed times and places can be assured, it is important that depots and posts having training functions be properly organized to conduct the training assigned to them.

TABLE IV
TRAINING REQUIRED BY EACH ARP SERVICE

ARP service and group	Individual training basic[a]	Local ARP organization	Individual training—advanced									Team training[b]	Combined training[b]
			Protection against H. E. Bombs	Protection against incendiary bombs	Protection against gas (full course)	Protection against gas (short course)	Decontamination course	First aid treatment (full course)	First aid treatment (short course)	Voluntary aid course	Special duties of group		
All ARP services:													
All ARP workers	5												
Air Raid Warden Service:													
All Air Raid Wardens	5	1	3	4	9	..	..	.	6	..	8	30	30
Fire Precautions Service:													
All auxiliary firemen	5	1	3	4	..	3	.	..	6	..	24	36	20
First Aid and Medical Service:													
All first aid parties	5	1	3	4	9	..	..	12	.	3	6	12	10
All first aid posts (Med)	5	1	3	4	9	..	..	12	.	3	6	20	10
All ambulance attendants	5	1	3	4	9	..		12		3	4	10	5
Rescue and Debris Clearance Service:													
All rescue parties	5	1	3	4	9	..	..	.	6	..	12	28	20
Demolition and Repair Service:													
All repair gangs	5	1	3	4	9	..	..	..	6	..	10[c]	30	10
Decontamination Service:													
All decontamination squads	5	1	3	4	9	..	6		6	..	10	10	10
Gas Identification Service:													
All G.I.Os	5	1	3	4	9	..	6	.	..	..	20	10	10
Command Organization:													
All report and control center staffs	5	1	3	4	..	3	..	..	6	..	20	20	20
Auxiliary services:													
All indoor workers	5	1	3	4	..	3	..	..	6	.	6	12	10
Drivers of ARP vehicles	5	1	3	4	9	..	..	..	6	..	4	10	5
Messengers	5	1	3	4	9	..	..	..	6	..	4	10	5

[a] Comprises elementary instruction in:
1. Organization for Civil Air Defense, 1 hr.
2. Protection against high explosive bombs, 1 hr.
3. Protection against incendiary bombs, 1 hr.
4. Protection against gas, 1 hr.
5. First aid treatment, 1 hr.

[b] Length of this training is a matter of local arrangement. The figures shown *are suggested averages.*

[c] According to special trade concerned.

Organization of Depots.—In each ARP service, the routine, training, discipline, and general efficiency of central reserve and operating depots is a responsibility of the Supervisor of the depot. In addition to responding to calls in an emergency, the operation of a depot involves:

1. Watches.
2. Drills.
3. Training.
4. Inspections.
5. Recreation.
6. Rest.

In time of war, *watches* must be maintained at all times, both day and night. Personnel should be detailed for telephone and other watch duties as required and should be regularly drilled in the action to be taken on an alarm.

Drills in responding to emergency calls, in dealing with fires in the depot, and for meeting other contingencies should be worked out and practiced regularly.

Daily *training* in ARP work should be given at each depot in accordance with general and local training plans and programs, in order to raise the standard of proficiency of all personnel. Training is a progressive and continuous process and must be well organized and methodically carried out. An important part of any training is physical exercise in the fresh air. This is essential for physical fitness and is best conducted through the organization of physical training classes, held for half an hour once or twice a day. Classes should always be held out of doors when practicable.

Periodic *inspections* of Government equipment, such as depot furniture, bedding, utensils, and individual clothing and equipage should be made systematically to ensure their proper maintenance and serviceability.

Recreation is essential to the contentment and morale of personnel and the maintenance of efficiency. Accordingly, a portion of the daily routine should be devoted to games, athletics, entertainments, competitions, and other recreational activities. Care should be taken not to require that an undue amount of spare time be devoted to organized recreations, in order to avoid excessive regimentation. On the other hand, idleness makes for discontentment and undermines *esprit de corps*.

In order to strike a proper balance among the various training activities and duties to be performed, a *daily schedule of operations* should be drawn up and systematically followed at each depot. In formulating a daily schedule, many varying factors must be taken into consideration: the type of depot, the shift system in force, the conditions of service, sex of personnel, and the season of the year. The following is an example of a typical daily schedule of depot routine in winter:

A.M.:

7:00– 8:00	Arising, dressing, making beds, cleaning up rooms
8:00– 8:30	Physical training
8:30– 9:00	Breakfast
9:00– 9:15	Roll call

9:15– 9:45	Inspection of equipment
9:45–10:00	Recess
10:00–12:30	Indoor instruction
P.M.:	
12:30– 1:30	Lunch hour
1:30– 4:00	Outdoor training; practice depot drills, fire drills, and other practical instruction
4:00– 6:00	Outdoor recreation, organized games, competitions
6:00– 7:00	Dinner hour
7:00–10:00	Indoor recreation, games, boxing, gymnastics, entertainments, discussions (optional) and evening classes on educational subjects
10:00 P.M.–7:00 A.M.	Rest. Also watch keeping for those on such duty (by roster)

Though routine schedules such as the above will necessarily vary in different depots, the principle is the same; *i.e.*, a daily schedule is drawn up, posted, and carried out.

Organization of Wardens' Posts.—As regards training, the Warden Service differs from the other ARP services in that (1) Wardens are scattered in small numbers all over the community; (2) their work is largely individual; and (3) the majority of Wardens are only part-time personnel. For these reasons, the depot training scheme employed for other ARP services is not wholly applicable to the Warden Service, although the principle of the daily training schedule is applicable. In lieu of depot training, Wardens are trained, during inactive periods, at District Wardens' posts under the supervision of the Warden. The following is an example of a typical daily schedule of a District Warden's post, for a stand-by period, during the duty tour of any Warden:

1. Report for duty and receive instructions from outgoing Warden.
2. Take over post, check property, and sign Warden's logbook, if all equipment is present and in order.
3. Test telephone line to city exchange, if no call has been made within 24 hr.
4. Each Warden makes tours of his sector at regular intervals, noting weather conditions and any other factors that might prove of value in the event of an air raid.
5. Each Warden carefully studies his sector to note all available shelter and locate other places where possible cover may be found; he also notes empty houses where fires may start.
6. Each Warden patrols his sector during hours of darkness so that he can find his way about and direct parties in the dark when necessary.

7. Each post conducts frequent exercises with its report center and adjoining posts.

8. At the end of each tour of duty, the post is handed over to the incoming Warden, as indicated above.

Individual Training—Basic.—Every ARP worker, regardless of the particular service in which he is enrolled, should be given this course, as soon after enrollment as possible (see Table IV, page 252). The training is arranged by the Assistant Director for Training and Operations (see page 237) or by the Chief of the ARP service in which the worker is enrolled. The instructors who conduct this training are qualified for this purpose by graduation from the central ARP school of the community. During the course in basic individual training, the ARP worker is carried as a supernumerary to his unit. Upon completion of the course, he becomes a full-fledged member of his unit and service and is entitled to wear the authorized ARP badge.

Individual Training—Advanced.—Immediately upon the completion of basic training, the advanced course of individual training is commenced. In the advanced course, the amount of instruction in each subject varies and is governed by the requirements of the particular ARP service, as indicated in Table IV (page 252).

Team Training.—Upon the satisfactory completion of basic and advanced individual training, team training is commenced. This form of training is designed to accustom personnel in each ARP service to work together as a team and to cooperate with another team of that service. Team training consists chiefly in practical work conducted out of doors by means of regular exercises, drills, and practices. It should be carried out by leaders of units and should form part of the normal duties of a shift at a depot or post.

The first exercises are simple drills to perfect procedure and can be held on any prearranged program, and finally several teams of the same service can be exercised together. These exercises are held under favorable conditions, *i.e.*, in daylight without gas masks or protective clothing. As proficiency is attained, more adverse conditions are introduced, such as darkness, masks, and protective clothing. Competitive drills and exercises are valuable means of promoting interest and efficiency in training.

The following outline of drills and exercises for the *team training* of *rescue parties* is typical of those prescribed for all other ARP services, except the Warden Service, which is mentioned specifically in the next paragraph:

Drills and Exercises for Rescue Parties

1. Dressing and undressing, according to standard instructions.
2. Preventive cleansing.
3. Formations for inspection.
4. Making up parties, when some members are absent.
5. Interchange of duties.
6. Dispatching rescue parties.
7. Provision and use of proper lamps at night.
8. Conducting exercises at night with decreasing light.
9. Erecting shores in conditions of increasing difficulty.
10. Dealing with danger of further collapse of buildings and walls.
11. Dealing with urgent leaks of gas, water, and electricity, until repair gangs arrive.
12. Rescuing trapped persons and recovering dead bodies from fallen debris.
13. Sending for additional assistance or materials.
14. Working by day and by night with and without full protective clothing.

The Warden Service presents certain peculiar differences from the other ARP services, and hence a special program of exercises is required. The following are the principal types of exercise for the team training of Wardens:

1. *Sector exercises,* conducted by an Associate Warden, to train the Assistant Wardens of a sector to work as a team under their Warden and to give them a detailed knowledge of their sectors.
2. *Post exercises,* conducted by a Warden, to teach the manning and uses of the post, cooperation between Associate Wardens of sectors served by the post, and to give knowledge of the district as a whole.
3. *General exercises,* conducted by a Principal Warden, in conjunction with the Controller of a report center, to practice Wardens in communications and cooperation between the Warden Service and report centers.

Combined Training.—When team training in each ARP service is completed, combined training of teams of the several services is commenced. The primary object of combined training is to give practice in cooperation between units of different services.

As a preliminary part of combined training (before combined exercises are conducted), each service should receive some instruction in the work and methods of operation of the other services, so that they may understand each other's problems. This instruction is generally imparted by appropriate lectures arranged by the heads of the various services.

Combined exercises are the principal means of combined training. They should be progressive, starting with minor incidents and working up to the larger and more complicated problems involved in heavy air attack. These exercises should be made as realistic as possible, and the lessons that each exercise is designed to teach should be thoroughly understood by all concerned.

An important feature of combined training is the preliminary reconnaissance on the spot by senior representatives of the several services to decide the order of priority of work. Thus, first aid parties may not be able to begin work until a fire company has extinguished a fire or the rescue parties have made the site safe from falling debris.

Combined exercises should be held at frequent intervals and may take the form of skeleton exercises in which no personnel is actually involved. Such exercises are of great value in testing communication systems and the Wardens' report routine.

Higher Staff Training.—This training is designed to qualify members of the ARP services for command and staff duty in divisional and higher echelons of the ARPD. It is usually imparted by means of large-scale command post exercises in problems involving the major aspects of the Civil Air Defense of the community. Exercises of this kind do not necessarily involve the active employment of the ARP services but usually take the form of paper plans in which members of the staff are required to work out solutions to assumed situations. The results of each exercise are checked against an *approved* solution of the problem, and the various phases of the problem are thoroughly discussed.

A typical problem for higher staff training is the movement of various ARP forces from one community to reinforce another in a serious emergency. These operations present a number of staff problems which require practice in order to avoid difficulties and disorganization.

Another type of problem to be dealt with in higher staff training is that of the sudden clearing of the population from an area under heavy air bombardment. This problem involves arrangements for orderly movements, use of transportation of various kinds, provision of food and housing accommodations where they are needed, and, last but not least, provision for allaying panic and preventing loss of public morale.

Higher staff training is intended for those responsible for the control and operation of the ARP services and should be conducted by the most expert instructors at the highest ARP school in the locality, *i.e.*, city or state.

Refresher Training.—Even after personnel have been fully trained by completing all the courses laid down in the general training plan, it is necessary to conduct refresher courses from time to time in order to keep abreast with improvements in technique and material and to ensure that instruction once received is kept fresh in mind. This is particularly important for instructors and those who are responsible for the training of others.

Special refresher courses for instructors should be conducted periodically at the central ARP school for the community (city or state), and local authorities should be held responsible for their instructional staffs taking full advantage of these courses. Local authorities are also responsible for arranging corresponding refresher courses for the local training of personnel.

Training of ARP Personnel in Industry.—Industrial and commercial establishments should be held responsible that all their employees know what they should do in the event of an air raid. They should also be required to see that a suitable proportion of their employees are trained in first aid, fire-fighting, and anti-gas measures and that they are properly equipped.

It is the duty of the local authorities to cooperate in the training of employees of industrial and commercial establishments in their localities by providing qualified instructors, by training instructors for service and in some cases by training the individual members of the company's ARP organization. The expense of this training should be reimbursed to the local authorities by the employers in accordance with mutual agreements. The details of this training are further discussed in Chap. XVI.

CHAPTER XVI

PROTECTION OF INDUSTRIAL ESTABLISHMENTS

General.—Although the local authorities in each community are responsible for the formulation and execution of measures for the protection of the civil population from air attack, these measures are intended collectively for the general security of the community as a whole and individually for members of the public at large. Therefore, no matter how effective these public arrangements may be, they will not suffice to meet the peculiar requirements of industrial establishments and private dwellings.

Large factories and commercial establishments are generally far more vulnerable to air attack than other activities in urban communities because of the concentration of buildings and personnel in small areas, the hazardous nature of the materials handled, and the natural incentive to hostile attack, *i.e.*, their military value. For these reasons, it is of the greatest importance that owners and managers of industrial plants, especially those employing considerable numbers of workers, take steps to protect their property from damage and ensure continuity of production when subjected to air attack, in so far as possible. To attain these ends, it is necessary to work out what will amount to a miniature self-contained Air Raid Precautions (ARP) plan, embracing as many of the various services as may be required.

As a rule, most factories and commercial enterprises have their own fire-fighting and first aid arrangements. These emergency measures provide a convenient nucleus around which to build an ARP organization. In most cases, the existing fire-fighting and first aid facilities will have to be considerably enlarged and the other ARP services will have to be provided from the ground up. In formulating an ARP plan for a factory or commercial establishment, it is important that the responsible heads work in close cooperation with the local authority in whose area their plants are situated. In this way, they may obtain assistance from the local authority in the matter of hospitalization and other ARP facilities and also may be able to help the local authority by making their own facilities available to the neighboring public in case of need.

Basic Considerations.—In approaching the problem of formulating an ARP plan for an industrial establishment, there are certain basic considerations that should be kept in mind. The most important of these will be briefly mentioned at this point.

Since the first air attacks may be delivered very suddenly, it is obviously impossible to provide the necessary protective measures at short notice, upon the outbreak of an emergency. It is therefore essential that an ARP plan be formulated and put into effect at each factory and commercial establishment in time of peace. This plan must include all protective measures that cannot be completed within a few hours after the Government declares the existence of an emergency. The necessary stores and materials for the completion of the plan must also be acquired in peace and stored ready for use.

As applied to an industrial or commercial establishment, the *objectives* of an ARP plan are

1. To safeguard the lives of the workers.
2. To limit bomb damage to the buildings and machinery of the plant, to the maximum extent practicable.
3. To protect personnel from the demoralizing effects of air raids and give them a sense of security and confidence.
4. To maintain production at the highest possible rate during air raids and reduce interruptions due to bomb damage to a minimum.

Since the danger of air attack with high explosive and incendiary bombs and gas is in every case local, the advantages of *dispersion* of both personnel and plant in minimizing these dangers are obvious. Hence, before drawing up any ARP scheme, full consideration should be given to means and methods of scattering the various units of a plant over as wide an area as practicable. This dispersion not only tends to reduce the damage from bombs but also helps to conceal the plant and make it a much less favorable target for hostile air attack.

In the matter of *physical protection* from bombs and gas, it is necessary to be quite clear in respect to the practical measures that can reasonably be provided against these dangers.

As regards *high explosive bombs*, it was shown in Chap. IV that overhead protection from direct hits of even medium sized bombs is enormously expensive and that such protection against the largest sized bombs is so costly as to be practically prohibitive. Accordingly, in ARP plans for factories and commercial establishments, overhead protection against direct hits of high explosives is not contemplated, except in special cases where natural facilities exist, such as near-by cliffs into which tunnels can be driven at reasonable cost. It is, however, practicable to provide reasonable overhead protection from falling debris and to provide lateral protection from the blast and splinters of high explosive bombs (see Appendix).

As regards incendiary bombs, it is practicable to provide overhead protection against penetration of the smallest size only (*i.e.*, 1-kg. electron bomb). Against larger sized incendiary bombs, protection against penetration is too expensive, except for very limited application in certain vital buildings. In all cases, however, personnel and the necessary equipment must be provided at the industrial plant to cope with fires from incendiary bombs (see Chap. X).

The chief means of *protection against gas* is the gas mask and protective clothing. These must be provided for all essential ARP workers; and, in addition, gas shelters should be made available for key employees who must remain on duty while an air raid is in progress (see Chap. VI).

Since many ARP duties, such as fire fighting, first aid, decontamination, and rescue and repair work, require previous *training*, provision must be made in time of peace to train a certain portion of the employees of a factory in these duties. The percentage requiring ARP training will vary from about 15 per cent in plants employing about 1,000 workers to approximately 5 per cent in large plants having about 10,000 employees. Training in rescue and repair work can usually be managed by the employer himself, but the balance of special ARP training can best be obtained by arrangement with the local authorities whereby plant personnel can attend local ARP schools (see Chap. XV).

Formulation of an ARP Plan.—In formulating an ARP plan for a factory or commercial establishment, it is important to distinguish clearly between action to be taken

1. In time of peace.
2. When an emergency appears imminent.
3. When an air raid warning is received.

4. During an air raid.
5. When a Raiders Passed or All Clear signal is received.

The plan should cover, in as complete detail as possible, the action to be taken by the employees of the plant. Thus, instructions to workmen on what to do when an air raid is expected should be prepared in time of peace, and ARP workers and those in key positions should be sufficiently familiar with these instructions to know what action to take in an emergency.

Outline of a Factory ARP Plan.—The circumstances in every industrial establishment are different; hence, any general outline of a factory ARP plan can be used only as a guide and must be varied to meet local conditions. The arrangements under any plan must be such as will stand the test of a crisis in time of emergency. This can best be ensured if those responsible visualize the scope and character of the difficulties that may arise in the event of air attack and make appropriate provision in their plan to cope with these difficulties.

The following is a typical outline of an ARP plan for a large industrial establishment:*

I. General organization.
    A. Controlling authority in peace and war.
    B. Instructions to:
        1. ARP personnel.
        2. Keymen.
        3. Workers generally.
    C. Cooperation with local authority.
II. Warning system and communications.
    A. Warning system.
    B. Intercommunication.
III. Concealment of lights.
    A. Screening of windows at night.
    B. Shading of lights.
    C. Extinction of external lights.
    D. Camouflage.
IV. Protection of workers.
    A. Shelters for workers.
    B. Instructions to workers.

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* Based on British practice, as outlined in *ARP Handbook No.* 6, "Air Raid Precautions in Factories and Business Premises," His Majesty's Stationery Office, London, 1938.

- *C*. Protection of keymen.
- *D*. Anti-gas protection.

V. Protection of buildings and machinery.
- *A*. Protection of vital parts.
- *B*. Transference of dangerous materials.
- *C*. Protection of essential supplies.
- *D*. Alternate sources of essential services.

VI. Emergency fire fighting.
- *A*. Arrangement with municipal fire department.
- *B*. Factory fire companies and parties.
- *C*. Fire drills for staff.
- *D*. Removal of inflammable stores.
- *E*. Water supplies.

VII. Rescue and repair work.
- *A*. Organization of rescue parties.
- *B*. Augmentation of repair gangs.
- *C*. Extra spare parts.

VIII. First aid and cleansing arrangements.
- *A*. First aid posts and cleansing centers.
- *B*. First aid parties.
- *C*. Ambulance service.
- *D*. Training of personnel.

IX. Gas detection and decontamination.
- *A*. Provisions for detection.
- *B*. Decontamination squads.
- *C*. Squad depots.
- *D*. Vehicle decontamination.
- *E*. Materials for decontamination.

General Organization.—The success of any ARP plan in coping with an air raid emergency depends largely upon the clearness and completeness with which it is worked out. The first step in the general organization of the ARP arrangements is the appointment of a definite individual as the controlling authority (ARP Officer) of the factory, with responsibility for drawing up the ARP plan and supervising its execution. The ARP Officer should be given authority commensurate with his responsibility and should have the wholehearted cooperation of all foremen and other plant personnel. As a rule, it is desirable that the member of the firm who is responsible for the preparation of the ARP plan in time of peace should also be made responsible for its execution in the event of war. Since nightwork in factories will be general in time of war, the ARP Officer and his key assistants should have one or more deputies to function during their absence or disability.

The next step in general organization under an ARP plan is to draw up an organization chart showing the component parts of the factory ARP organization, their functions and relations with each other, and the general scheme of control. Figure 39 shows a typical organization chart for a large industrial establishment.

Having set up the required control organization and appointed officers and assistants for each major function under the ARP plan, the next step is to determine what part of the factory personnel will take cover in shelters during an air raid and what part must remain at their posts of duty. Direction as to these points should be clear and distinctly understood by all concerned. Arrangements must also be made to prevent factory workers from taking cover unnecessarily and thereby interrupting production when it is not essential. Careful consideration must be given this matter and effective measures of control provided.

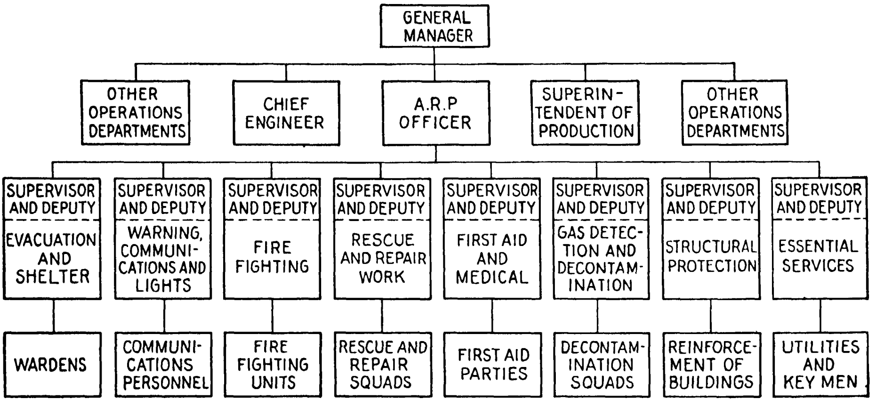


FIG. 39.—Factory. Air Raid Precautions organization.

In the general organization of a factory ARP plan the various tasks should be definitely allotted to designated persons and the list should be kept up to date. As a rule, young workmen who are liable for military service in time of war should not be chosen for ARP service, as they may be called to the colors at a time when trained men for these duties are most urgently needed. Factory and plant personnel designated for emergency fire fighting, first aid, and decontamination work should be given the necessary training for these duties. *Definite instructions* should be formulated for *key workers* who must remain on duty and suitable means provided for their protection while performing these duties. Certain of these keymen attend to such duties as turning off gas and electricity, attending to boilers, and similar work, and they can often be incorporated with the nearest fire-watching party. Where this cannot be done, protected accommodation, usually constructed with sandbags, must be provided. Keymen should always be posted in pairs in case of casualties.

The ARP plan for a factory or commercial establishment should carefully define the respective responsibilities of the owners and the local authorities. Though full advantage should be taken of the public facilities for training, hospitalization, etc., furnished by the local authorities, adequate provision should be made to meet the additional needs peculiar to the establishment.

Equipment not readily available in an emergency should be acquired in time of peace and stored in convenient locations. Definite arrangements should be made to secure other necessary equipment quickly and with certainty when needed.

Finally, it is of the utmost importance that the plan include all practicable means and measures for maintaining production with the minimum interruption during air raids without incurring avoidable risks to factory and plant personnel.

In many factories and commercial establishments, existing fire alarm systems can be utilized for air raid alarms by adopting a distinctive signal for each purpose. Thus, for fire alarms the bells or horns may sound continuously for several minutes, whereas for air raid alarms the sound may be intermittent. Again, it is necessary to have a distinctive signal to indicate the presence of gas, when the raiders have passed, and when all is clear. These signals should, of course, be transmitted to all shelters used by factory personnel.

As a rule, shelters are built so that they can be occupied by the factory workers they are intended to protect in about 5 min.; hence, a warning period of about 7 min. is all that is necessary in the usual case. In order to prevent loss of time by workmen seeking shelter when preliminary warnings are sent in, while the hostile raiders are still 20 or 30 min. away and may not fly over the factory locality at all, many factories find it advantageous to supplement the public air raid warnings by placing a series of *lookouts* on the roofs of the principal plant buildings. These men go on the alert when the public warning is received and keep a sharp watch for approaching planes. When hostile planes are sighted flying in the direction of the plant, these lookouts give the signal to factory personnel to take cover in sufficient time to enable all workers to reach their shelters. In this way, loss of working time from false and premature air raid alarms is avoided without jeopardizing the safety of factory workers.

Since no assurance can be had that the commercial telephone will remain in operation in time of war and air attack, suitable arrangements should be made for *emergency methods of communication* between different parts of a plant and to vital outside places. Such alternative methods of communication comprise the use of factory telephone systems, emergency field telephones, runners, bicycle and motorcycle messengers, and short-wave radio sets.

Warning System and Communications.—We have said in Chap. VII that it is the duty of the Aircraft Warning Service to bring warning messages of approaching air attacks to the gates of a city and thereafter it devolves upon the mayor or other designated local authority to spread the alarm throughout the city. Similarly, the local authorities bring these warning signals to the gates of a factory or other commercial establishment, and it is then the responsibility of the management to ensure that the warnings are conveyed to the workmen throughout the plant area. This is the function of the *factory warning system.*

Where a factory is within an area of the city covered by a public warning siren, it will be expected to rely on the public warning thus conveyed. On the other hand, if the factory is located in a remote situation near the outskirts of the city, so that it is not within range of a public siren, the management must arrange with the local Director of ARP to have his establishment placed on the authorized telephone list of recipients of air raid warnings. In this case, the management will designate an official (usually the factory Supervisor of Alarms and Communications) to receive air raid warning messages and to take action thereon. It will often be desirable to provide means of conveying the warning to certain selected keymen who are instructed to take preliminary action thereon, before the warning is issued to factory personnel generally. This will tend to prevent unnecessary loss of time from workmen leaving their work for false alarms and before it is actually necessary to take cover.

When it becomes necessary to spread an air raid alarm through a factory, time is important and not a second should be lost in taking the action required and in reaching all the personnel of the plant. This can generally be best accomplished by a system of alarm bells or horns which are all electrically operated from a central point where the city alarm is received at the factory.

The ARP organization of each factory and commercial establishment requires a control post from which the work of the ARP personnel can be directed and coordinated. The control post should be located in the best-protected and gas-proofed shelter available near the permanent office of the ARP Officer of the plant. The control post should have telephone communications with an alternate messenger service to all important parts of the plant. The telephone over which public air raid warnings are received at the plant and the main line power switch for extinguishing all lights should be located in the control post. In large plants, subsidiary control posts may be necessary, in which case additional manning details will be required.

It is particularly important that communications between the control post of the plant and the local authorities be maintained at all times. When the regular factory telephone exchange is evacuated during an air raid, an alternate exchange in a protected shelter should be arranged so that communication can be by-passed around the regular exchange and routed through the emergency switchboard.

Concealment of Lights.—In time of war, lights visible at night are restricted not merely to prevent conspicuous buildings from being picked out from the air by hostile bombers, but also to deprive the enemy pilots of an easy means of guiding and checking their flights. Therefore, the *restriction on factory lighting* is not only for the protection of the plant, but also for the protection of the whole neighborhood.

Except in the case of certain industries, such as steel mills and blast furnaces, which are dependent on unscreened lighting and emit a glare, all factory lights visible from the outside are prohibited in time of war. Even those industries of the type mentioned must take steps to screen or obscure all visible lighting and glare when an air raid warning is received (see Chap. VIII, page 186).

Since all outdoor lights are extinguished, arrangements must be made by the management for *marking* all *roads and pathways* in the plant area by white posts or stones, for the guidance of those who have to use them at night. In some cases, guide lights, shaded to conform to public traffic signal standards, may be permitted when specially authorized by the local authorities.

In order of efficiency, the various methods of *obscuring skylights* that will not shut out daylight are

1. External and adjustable weatherproof panels.
2. Internal panels, sliding or hinged, of light weatherproofed material.
3. Blinds of opaque material.
4. Complementary lights, *e.g.*, skylights of blue and artificial lights of yellow.

Where none of the foregoing methods can be applied, obscuration with exclusion of daylight as well may be effected by

1. Opaque paint, special waterproof gummed paper, or other opaque materials.
2. Panels fixed permanently over the skylights upon the outbreak of the emergency.

If there are openings in walls, panels should be hinged or fixed in place lightly, so that when subjected to blast they will swing freely or will come away as a whole and may be replaced.

When the Take Cover signal is given, it is usually advisable to extinguish all factory lights by pulling the main power line switch, in order to avoid the escape of light in case window or door closures are blown open. To assist workers to evacuate factory buildings speedily and reach shelters at night, a system of dim, blue *pilot lights* must be maintained inside the factory buildings. These lights must be separate from the factory power system and should be run from independent batteries or oil lamps. Such independent lights should also be provided in all shelters and ARP workers' accommodations.

Wherever practicable, *water, gas, and electric mains* serving the factory buildings should be widely separated and arranged in closed loops, so that a direct hit of a bomb on one main does not affect the other or put the service out of action. If within reasonable financial limits, an alternative or independent supply of vital services (water, gas, electricity) should be arranged.

Protection of Workers.—The provision of effective protection for workmen is one of the most important problems with which employers will be faced in time of war, and in making plans for this purpose certain essential principles should be borne in mind.

Large congregations of persons in one place should be avoided. As a rule, not more than 50 people should be gathered in one place, unless the room is divided into compartments with splinter-proof partitions of concrete, sandbags, or boxes of earth, in order to localize the effect of any explosion.

Shelters should be gas-proofed and protected against blast and splinters, according to the standards mentioned in Chap. IV. In addition, employees should keep their gas masks with them, ready for use at a moment's notice.

Personnel of factories and commercial establishments may be protected by any of the following means:

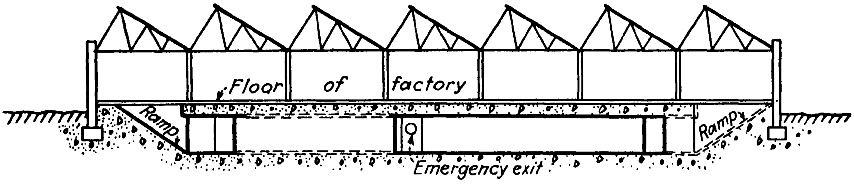
1. By shelters in existing buildings.
2. By trenches or other outdoor shelters.
3. By galleries and tunnels.
4. By dispersion.
5. By a combination of any of the foregoing.

Shelter accommodations must be provided for the maximum number of workers present at any one time, excluding change-over of shifts which should be staggered in time of war. In some plants, natural shelter, such as mine galleries and tunnels, may be available for a portion of the personnel, or suitable shelter may be provided at home for those who live within 5 min. walk of their place of work. These cases are exceptional, however, and as a general rule the management must figure on the protection of at least one shift of the working personnel.

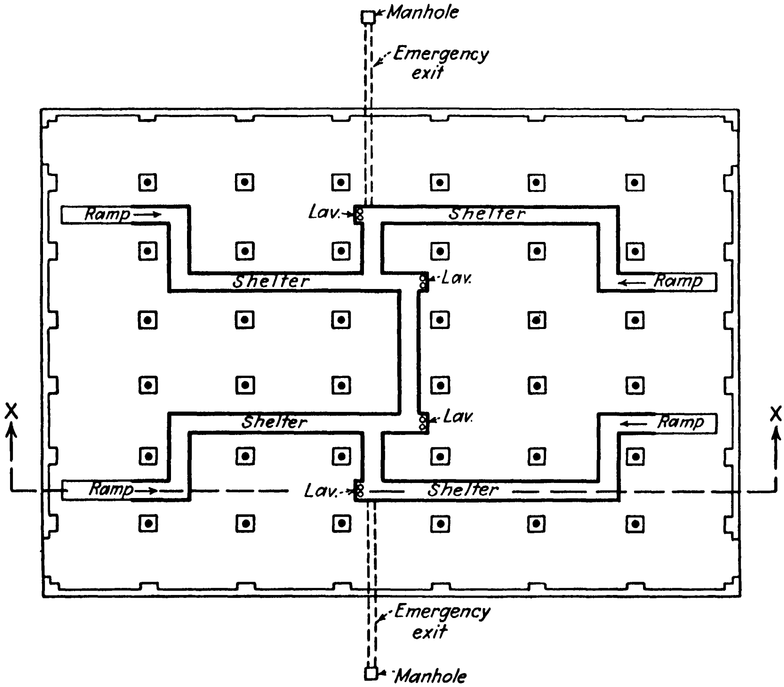
The first step in drawing up a shelter plan is to make a careful survey of the existing buildings and facilities of the plant and utilize all places where suitable shelter accommodations exist or may be provided by structural alterations. The occupant capacity of all shelter space available may be calculated as explained in Chap. VI.

The shelter capacity of existing buildings in the plant area having thus been determined, the next step is to survey all accessible land on which shelters holding 50 persons each may be constructed. The adjacent edges of neighboring shelters should be never less than 25 ft. and, wherever possible, 30 ft. apart for underground shelters and at least 50 ft. apart for surface shelters. With such spacing, 1 acre of land will accommodate about 1,000 persons in underground shelters or approximately 600 in surface shelters.

Where sufficient accessible land is not available for the construction of outdoor shelters, consideration should be given to erecting shelters under existing plant buildings. By careful siting, underground shelters may be constructed between the foundation walls and column footings of buildings without impairing the structural integrity of the building. Figure 40 shows a typical layout of such a shelter.



ELEVATION-SECTION X-X



PLAN

FIG. 40.—Shelter under factory building.

As a general rule, shelter accommodation below ground level is best, provided that the ground is not waterlogged and protection from gas is secured. With multistory reinforced concrete or steel frame factory buildings, it is generally preferable to locate shelters in or under the basements of the buildings, rather than out of doors, since such buildings do not collapse as a whole when struck by even heavy high explosive bombs. All that is necessary in such buildings is to reinforce the roof of the shelter to withstand the load of falling debris, as explained in Chap. IV.

On the other hand, factory buildings of light masonry construction and two or three stories in height will usually suffer heavy damage from high explosive bombs; it is therefore preferable in such cases to arrange for shelters out of doors. Single-story industrial buildings with large areas of skylights are particularly vulnerable to high explosive bombs, and the danger of flying glass requires even greater distances for outdoor shelters of the open trench type.

The same general principles govern the location and construction of factory shelters of various types as in the case of corresponding types of public and private shelter (see Chap. IV).

Once the locations, types, and sizes of shelters for a factory have been determined, the whole construction project should be examined to see what portions of the work should be undertaken in time of peace and what additional work would be required to complete the shelters when an emergency appears imminent. Although the extent of the work that can be carried out in time of peace depends upon local conditions and facilities, it is of primary importance that plans should be prepared in detail and the necessary material either accumulated or located in such a way that it can be made available on short notice when required.

Protection of Buildings and Machinery.—As it is generally impracticable to protect the whole of an industrial plant, the first step in formulating a plan of plant protection is to classify which parts of the plant are vital and which are not. After a decision is reached as to the vital installations, a survey should be made to see what can be done to afford local protection against damage by blast and splinters, especially for machinery that is essential to the continued working of the factory. In principle, the standard of overhead protection and of lateral protection up to at least the height of the vital parts to be protected should be applied (see Chap. IV, also Appendix).

Particular attention should be paid to the protection of steam boilers, electric generating stations, essential gas and water supply mains, electric power and telephone cables, and switchboards. The rupture of supply conduits may cause, not only dislocation of production, but also dangerous explosions and the flooding of underground shelters. In considering the protection of vital parts of a factory, the need for providing adequate shelter for first aid posts and other ARP activities, as well as for key workmen who must remain on their jobs during air raids, should not be overlooked. In most cases, sandbags will afford the simplest and most effective means of protection, but wooden boxes filled with earth will serve nearly as well.

Emergency Fire Fighting.—Since even the smallest incendiary bombs will penetrate all ordinary roofs and burn on the floor of the top story, it is most important to take all possible steps to reduce the risk of fire in factories by fireproofing the top stories of buildings and by providing means to extinguish fires quickly (see Chap. V). It is impracticable to deal effectively with incendiary bombs burning in top stories and other confined spaces that contain masses of inflammable material; hence, steps must be taken to clear such vulnerable places of all possible inflammable materials.

Special consideration must be given to highly inflammable substances, such as gasoline and fuel oil in tanks, on account of the grave risk of fire. Plant areas containing storage tanks of inflammable liquids should be subdivided by earth traverses to prevent the spread of burning liquids. In general, inflammable liquids should not be stored on the top floor of a building; where this cannot be avoided, a drainpipe to an outside sump should be provided to prevent such liquids from dripping down on floors below. It is equally important to segregate the storage of inflammable liquids and other hazardous materials in separate storehouses which should be located as far as possible from other buildings in the plant area.

The fire hazards about the plant having been reduced as much as possible, the next step is to see that adequate arrangements are made to fight fires. As a rule, most industrial plants have fairly well-organized fire-fighting arrangements to deal with fires from industrial causes. However, since the risk of fire is far greater in time of war, because of the large coverage of incendiary bombs from a single airplane, the ordinary peacetime fire-fighting means must be considerably augmented in both personnel and equipment. In short, it is essential that every factory should be able to rely on its own resources both as regards fire-fighting appliances and water supplies.

A small factory employing about 250 persons requires a minimum of 3 fire watchers and 1 fire party of 6 fire fighters, whereas a large industrial plant having 10,000 employees should have at least 27 fire watchers and 3 fire parties of 12 fire fighters each. Fire watchers should be organized in two reliefs and fire fighters in three reliefs.

In addition to the organization of fire watchers on roofs and of fire parties with light, portable fire-fighting appliances, large factories and industrial plants will also have to organize special fire companies, with heavy pump equipment, capable of subduing serious fires that may occur when the city fire department is not available. The organization, equipment, and operation of these fire-fighting means are described in Chaps. V and X.

Finally, the question of adequate water supplies should receive special attention. As the city water supply may be too low to fight large fires or may fail altogether from bomb damage, during an air raid, each industrial plant should have its own water storage tank which can be cut off from the city mains, if necessary. This tank should preferably be underground and should never be located on the roof of a building where it might readily be ruptured by bomb blast or splinters.

Rescue and Repair Work.—When an industrial plant is attacked with high explosive and incendiary bombs, the buildings that are struck are liable to be more or less completely demolished or damaged by fire. In either case, collapsing roofs, floors, and walls may bury or trap occupants of the building under debris from which they can be quickly extracted only by men trained in such work. Hence, it is necessary that each industrial plant have available one or more trained rescue squads which are organized and equipped to rescue persons trapped by fallen debris and to recover dead bodies from demolished buildings. These squads are also trained quickly to remove debris from roads and passageways so that the circulation of traffic in the plant may be restored.

The number of rescue squads will vary according to the size of the plant; the minimum for 1 relief in a small factory employing about 250 persons being 1 squad of 6 men, whereas a large industrial plant having 10,000 employees will require for 1 relief not less than 6 such squads. Rescue squads are organized into day and night reliefs, are located in the vicinity of their equipment, and are provided with splinter- and gas-proof shelter accommodations. Each squad is furnished with special motor vehicles to enable it, in an emergency, to reach any part of the plant area speedily.

Since vital supply services (water, gas, and electricity) and essential parts of an industrial plant, such as steam boilers, powerhouses, and production machinery, may be damaged during an air raid, resulting in a more or less complete dislocation of operations, it is imperative that special arrangements be made for effecting speedy repairs in such cases. This is usually accomplished by adding to the regular repair and maintenance forces of the plant one or more special repair gangs, composed of artisans skilled in the various mechanical trades required for such repair work. These repair gangs are organized into two shifts and are trained and equipped to repair essential utilities and machinery used in the plant.

The personnel and method of operation of rescue squads and repair gangs in industrial plants are essentially the same as those maintained by the Rescue and Debris Clearance Service and the Demolition and Repair Service for the general public, as described in Chaps. XI and XII.

In order to ensure rapid repairs to damaged plant utilities and machinery, each industrial establishment should keep on hand a stock of spare parts available for instant use in case of need.

First Aid and Cleansing Arrangements.—Most factories and industrial establishments have some arrangements for administering first aid treatment to their employees in case of accidents. These facilities vary all the way from the simplest first aid station to the completely equipped infirmary, depending upon the size of the plant, the hazardous nature of its work, and its proximity to municipal hospitals.

In time of war, when industrial establishments are subjected to air attack the number of casualties that occur at any one time may greatly exceed those resulting from industrial hazards. Hence, the first aid facilities used in time of peace in most factories are generally too meagre to be adapted as a *first aid post* for ARP requirements. These facilities may, however, serve as a nucleus around which to build an adequate first aid post. This may be accomplished by utilizing buildings adjoining a first aid post and suitably altering and equipping them for the purpose.

It is essential that the whole of the premises chosen for a first aid post be adequately protected and gas-proofed and that the layout conform generally to the standards laid down for a public first aid station (see Chap. IX).

In addition to first aid facilities, a *gas cleansing center* will be needed in each factory to deal with cases of contamination by toxic gas. Wherever practicable, the cleansing center should be close to or a part of the first aid post, so that wounded, contaminated personnel can be cleansed in the cleansing center before entering the first aid post.

The equipment of a cleansing center should consist of shower baths, with hot water, bins with close-fitting lids for contaminated clothing, and a supply of fresh clothing to replace that which is contaminated. Since the risk of injury increases with every minute of delay in cleansing contaminated persons, every factory and shop should have a cleansing center, and large plants should have two or more, conveniently located for the plant area they serve. Factory washrooms and lavatories having hot-water supplies may often be utilized as gas cleansing centers, provided that they are suitably protected and gas-proofed. Weatherproof sheds should be constructed at the entrance to a cleansing center where contaminated persons can take off and leave behind them their contaminated clothing.

If existing accommodations cannot be found, a combined first aid and cleansing center will have to be constructed, as described in Chap. IX. When both sexes are employed in a factory, separate first aid and cleansing facilities will be required for men and women.

A medium sized factory, employing about 1,000 persons, will require 1 first aid post manned by 4 attendants (women if possible), whereas a large factory, having 10,000 employees, will need at least 2 first aid posts, each manned by 6 attendants. Similarly, a factory with about 1,000 employees should have 1 cleansing center manned by 4 attendants (men or women), whereas a factory with 10,000 employees should have at least 2 centers, each manned by 4 attendants.

It is unnecessary for small factories, employing less than 500 workers and located in an urban community, to provide a first aid and cleansing facility, as indicated above, since war casualties in such factories can be handled in the existing factory first aid station, if sufficiently protected, or by the local authorities. As the local authorities are responsible for the evacuation, hospitalization, and medical treatment of casualties in factories and industrial establishments as well as those among the general public, it is unnecessary for these plants to provide such facilities within the plant area. They should, however, arrange with the local authorities as to the method of transporting casualties and the particular hospital to which they will be sent.

Gas Detection and Decontamination.—When gas is dropped on a community during an air raid, it is the duty of the Air Raid Precautions Department (ARPD), and especially of the Warden and Gas Identification Services, to notify the public of the presence of gas in the affected area and the particular kind of gas used. For industrial plants, especially those having many buildings and covering considerable areas, it is not enough to know that gas has fallen generally in the vicinity; the management must also know what buildings and parts of the plant are involved in each gas attack. For this purpose, each plant should have scattered throughout the plant area chemical detector panels and painted surfaces which will show by characteristic stains just where the gas has fallen.

In addition, each plant should provide one or more *gas searchers,* located in protected shelters and equipped with special gas detection equipment (see Chap. XIII). These gas searchers, fully protected with masks and anti-gas clothing, search the plant premises for contaminated areas, during and just after a gas attack. Where an industrial plant covers a considerable acreage, the area is subdivided into zones and each zone is made the responsibility of a particular gas searcher. In this way, a large area may be quickly and effectively searched.

Gas searchers must be specially trained in gas detection work and should cooperate closely with the local Gas Identification Officer, so that they will know what action should be taken to deal with each situation. Their work in this connection is purely advisory to the decontamination personnel, and they do not participate in actual decontamination work. For a small plant, employing less than 1,000 workers, 1 gas searcher is generally sufficient; a large plant, with 10,000 employees, will require 4 searchers. For very small plants, having less than 250 employees, gas searching and detection can normally be performed by members of the decontamination squads.

As public *decontamination squads* may be fully occupied with the decontamination of streets and other public places and thus may not be available, the managements of industrial plants should make their own arrangements for decontamination of plant buildings, equipment, and material.

For this purpose, an establishment employing less than 1,000 workers should have at least 1 decontamination squad of 6 men; establishments employing over 1,000 workers should have 2 squads. If the plant area is very extensive, the number of squads should be proportionately increased. In estimating the number of squads needed, it may be assumed that 1 squad of 6 men will require about 2 hr. to decontaminate an average area contaminated by a 50-lb. gas bomb.

The organization, equipment, and methods of operation of factory decontamination squads are essentially the same as those of public decontamination squads, mentioned in Chap. XIII. As decontamination work requires special training, the management of an industrial establishment should arrange with the local authorities for the training of their squads. Special arrangements should also be made by each plant to decontaminate its vehicles, and also the clothing of personnel that has become contaminated.

New Factories and Commercial Establishments.—What has been said above applies primarily to existing plants that were built without any regard to protection against air attack. In the case of new plants, which can be specially designed and constructed with a view to resisting air raids, much can be done to improve the protection of personnel and property.

Since it is generally impractical to protect factory buildings from direct hits by high explosive bombs, the best safeguard to maintenance of production is the *principle of dispersion* which should be applied not only to the location of individual buildings, but also to the layout of the plant area itself. It is obviously much easier and less expensive to incorporate means for air raid protection in the design of a factory than to add it after the factory is built.

The following measures of protection for new factories and commercial establishments are based upon British practice.* Measures for the *protection of personnel* are as follows:

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* "Air Raid Precautions for Government Contractors," pp. 23–35, His Majesty's Stationery Office, London, 1939.

1. Shelters should be provided for the maximum number of persons present at any one time.

2. Shelters should be constructed under the ground floor or basement of the factory.

3. Sufficient ground should be available for the erection of such outdoor shelters as may be necessary.

In the *layout of the plant,* the principle of dispersion should be applied and separate buildings with splinter-proof walls adopted instead of housing all parts of the plant in one building. Where large buildings are required for closely associated operations, they should be subdivided by splinter-proof partitions, so that, in general, not more than 50 persons will work in any one room. Storage and other nonoperating rooms may be located between operating rooms, so as to form buffers against blast and splinters.

The following *standards of construction* are preferred:

1. Type—steel frame with brick panels.

2. Roof—reinforced concrete, 5 in. thick, erected in terraces with vertical windows between terraces.

3. Walls—13½ in. thick, of standard brickwork, or 15½ in. of hollow tile, filled with sand.

4. Windows—long in width and narrow in height, with sills above the level of personnel working in the room.

5. Materials—all glass should be of the integral wire shatter-proof type, colored to harmonize with the surroundings.

If the foregoing standards of construction cannot be adopted throughout the plant, they should at least be applied to the most vital parts thereof.

All control posts, first aid posts, cleansing centers, and accommodations for fire-fighting apparatus should be splinter- and blast-proof, with a 6-in. concrete roof.

Arrangements must be made for the complete obscuration of lights after dark throughout the war period, and all windows, doors, and skylights should be specially designed with this in view.

Alternative sources of supply for water, gas, and electricity should be provided and all service mains and conduits arranged in loop circuits with adequate protection from blast and splinters.

All buildings and structures should be camouflaged and built so as to be as inconspicuous as possible from the air.

If the foregoing measures are incorporated in new factory buildings, a substantial increase in protection of both personnel and plant will be achieved.

CHAPTER XVII

PROTECTION OF THE HOME

General.—Despite the most far-reaching and effective measures for protecting the civil population in streets and public places and the most elaborate and efficient schemes of air raid protection in factories and business premises, it is impossible to devise a plan of air defense that will cover everybody unless each householder and family play their parts in doing what they can to protect themselves. For this reason, notwithstanding that the municipal authorities will provide measures of air raid security for all citizens while in the streets and public places and employers will safeguard their employees while at work, it is the duty of each householder to protect his home and family to the full extent of his ability. In meeting this responsibility, he will be guided by the technical information and advice published by the national Government and will be assisted by the local authorities. But notwithstanding these aids, the duty of informing himself of the nature of air raid dangers and what he can do to protect his home and family rests with each individual householder alone.

The importance of home protection is apparent when it is remembered that, of the 168 hr. in the week, the average citizen works at his place of business 40 to 48 hr. and spends 12 to 20 hr. in the streets and other public places and the remainder of the time (about 100 hr./week) at home. This means that during the weekly cycle of urban life the chances are about 3 out of 5 that if the community is bombed the attack will occur while the working people are at home. Actually, the chances of an individual being bombed at home are even greater than 3 out of 5, since the large majority of the urban population work in the daytime, whereas most air raids are carried out at night, and since the nonworking members of the family spend an even larger percentage of their time at home. And so it is of the utmost importance that the individual householder be fully aware of the dangers that threaten his home and family when his community is subject to air attack.

Many of the measures of protection that can be put into effect in the home are relatively simple and inexpensive. Other means of protection, such as blast-proof and gas-proof shelters, may involve considerable expenditure of money which the average householder cannot afford, without some government assistance. This may take the form of outright grants of money, where the householder meets certain required standards of construction and other official stipulations, or it may consist of reductions in property or income taxes or of other forms of subsidy. These are matters which are generally regulated by national statute in which the air raid precautions (ARP) policy of the Government is set forth, together with measures of protection that are made mandatory.

The Problem of Home Protection.—The problem of air raid protection of the home and family is essentially the same as the protection of any other building and its occupants and consists fundamentally in the following, in the order of relative importance:

1. Means for protection against high explosive bombs (shelters).
2. Means for protection against incendiary bombs (fire precautions and combative measures).
3. Protection against gas (masks and gas-proof rooms).

The general principles and methods of protection against high explosive and incendiary bombs and gas have been discussed in previous chapters, and only their special application to the protection of the home remains to be considered here.

Shelter.—There are three general ways in which a household may be provided with shelter: (1) A shelter may be constructed underground, either under the house or out in the back yard. (2) A semisurface or surface shelter may be built of brick, concrete, or sheet steel, either into or attached to the house. (3) The natural protection of the house can be increased by forming a "refuge room." The first and second methods afford better protection against bomb splinters but are more expensive than the third. Where a house is of light wooden construction, refuge rooms do not give adequate protection and the other types of household shelter are the only means of securing reasonable safety. Notwithstanding the superiority of specially constructed household shelters over refuge rooms, the difference in cost will probably result in most householders adopting the latter, not only because it is cheaper, but also because most of the work of preparing a refuge room can be performed by the average householder himself, with materials at hand.

Types of Domestic Shelter.—The simplest and cheapest type of outdoor shelter is an open trench which gives complete protection against bomb splinters and very good protection against blast, except in the very remote event of a direct hit in the trench. The open trench has several practical disadvantages. It affords no protection against gas or falling splinters of antiaircraft shell and is most uncomfortable in rainy and cold weather, since it does not keep out the rain and is impossible to heat adequately. These disadvantages can be largely eliminated by covering the trench with from 2 to 2½ ft. of earth, supported by timber, or corrugated iron as described on page 99 and illustrated in Fig. 16.

Provided that covered trenches are spaced a safe distance away from the house (more than half the height of the walls), they afford far greater protection than any room in an ordinary dwelling house, and even the majority of refuge rooms. And where expense precludes constructing a refuge room in the house conforming to the standards of protection mentioned in Chap. IV (pages 104, 105, and 106), covered trenches or dugouts with a minimum of 4 ft. of overhead cover are much to be preferred. The only practical disadvantage of such shelters that cannot be overcome is the discomfort and trouble of leaving a warm house on a cold wet night to reach the shelter. Against this must be weighed the greatly increased protection of a well-constructed covered trench or underground dugout shelter over the best protection afforded by refuge rooms in houses.

The next most economical form of outdoor shelter for households is the semisurface type, formed by placing preformed arched sections of sheet steel ("Anderson" type) or reinforced concrete in a trench 3 or 4 ft. deep and covering the sections with the excavated earth to a depth of 2 to 2½ ft. These shelters, when properly erected, give as much protection as the covered trench and are preferred wherever the ground is too hard or too waterlogged to allow deep digging.

Although the most expensive, the best form of domestic outdoor shelter, from the standpoint of comfort and convenience, is the surface shelter which is essentially a pillbox, constructed of brick or concrete of sufficient thickness to afford protection against bomb blast or splinters (see Chap. IV, page 106).

Refuge Rooms.—A refuge room is generally provided by selecting a room that, because of its location and construction, affords the best natural shelter in the house and then improving its protective value by certain appropriate expedients. Accordingly, the first step in providing a refuge room for the household is to pick out the best room in the house for this purpose. A room below ground level is preferred for a refuge room because it affords the best natural protection against bomb blast and splinters. Where the house does not extend below the ground level, very good protection can still be obtained aboveground by enclosing the refuge room by walls of brick, stone, or concrete (see Chap. IV, page 105).

Selection of Refuge Rooms.—The basic principle in selecting a room for use as a refuge is to choose one that is as well protected as possible by surrounding walls of masonry, including those of the house next door, in order to secure the maximum protection against flying bomb splinters. Though it requires 13½ in. of brickwork to afford full protection against bomb splinters, a 9-in. brick wall will stop the majority of them; where the required thickness of brickwork is not found in the wall of the refuge room, the thickness of all walls within a distance of about 30 ft. therefrom may be considered as added to that of the room walls. In this connection, it is important to make sure that the walls of the refuge room are of solid masonry and not of wooden framing covered with stucco or brick veneer.

As a general rule, a small or narrow room is preferred for refuge purposes, provided that it has sufficient area and cubic space to meet the ventilation requirements specified in Chap. VI (pages 154–155), for the reason that its roof or ceiling will be more resistant to the load of falling debris than a room of wider span. Where material and labor are available for propping up the ceiling over the refuge room, it is not so important to choose a small and narrow room. Because of their vulnerability to blast and splinters, large windows, and especially bay windows, should be avoided in selecting a refuge room.

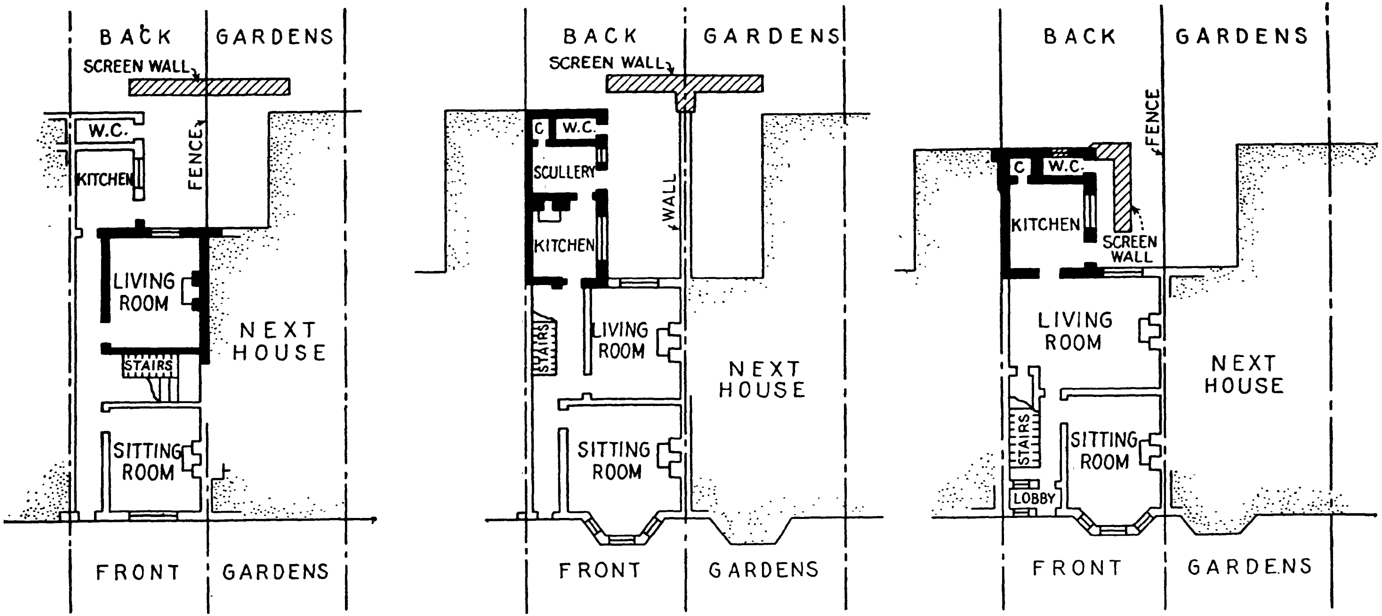
In houses having basements below the ground level, the kitchen or pantry will often be found most suitable for a refuge room, particularly if the outside door faces the next house or a pantry wall. A coal cellar under the pavement or back yard also will make a good refuge room, without alteration, provided that it has an emergency exit, which can often be improvised by enlarging the coal chute. Figure 41 illustrates how refuge rooms should be chosen in typical houses and improved by outdoor construction.

Windows and Doors of Refuge Rooms.—Where outside windows and doors of refuge rooms are not shielded by another house or solid masonry wall within a maximum distance of 30 ft., it is necessary to provide protection against bomb blast and splinters. This can best be done by blocking up the window or door openings with brickwork or other equivalent closures or by erecting a barricade of brick or sandbags outside the openings, as described in Chap. IV (pages 105 and 108).

Whatever the form of blockage or barricade, it should not completely close window openings but should be carried up to a minimum height of 6 ft. above the floor level, so as to protect those walking about in the room. This will generally leave an open area at the top of the window through which air and light can enter the room. An inside screen should be fitted over this open area to prevent escape of light during blackouts, to keep out gas, and to prevent flying splinters of glass in case the windowpane is broken by bomb blast (see pages 105 and 153).

Gas-proofing.—After the windows and doors of a refuge room have been protected, the next step is to make the room as gas-proof as possible. Since no serious amount of gas will enter a room unless there are drafts of air to carry it in, the first step is to stop up all extraneous openings from outdoors. This can be accomplished by filling all cracks and crevices in the walls and ceilings with putty or a pulp made of wet newspaper or by pasting them over with strong gummed paper, as explained in Chap. VI. All trap doors, skylights, and ventilators should be sealed; if there is a fireplace, the flue should be stuffed up with rags, paper, or sacks, or, better still, the opening into the room closed with a sheet of plywood and adhesive tape. Care should be taken to seal up all cracks between and around window sashes and a gas curtain should be fitted to all doors, as explained in Chap. VI (page 151). After a refuge room is thus rendered gas-proof, it can still be used for ordinary living purposes by temporarily removing the closure of the fireplace when it is necessary to have a fire (see Fig. 26).

Fire Precautions.—The fire precautions and methods of dealing with incendiary bombs, described in Chaps. V and X, apply in general to the protection of the *home* against incendiary attack; but the expense of much of even the simpler fire-fighting equipment



In this case the living room affords quite good protection as all the walls are well screened and the only place where splinters could enter is the window. The chances of this are small but a screen wall across the opening would protect the window

Kitchen and scullery provide good refuge rooms as they are, but would be improved by the erection of screen walls across the back yard

The kitchen would provide the best refuge room since the living room is vulnerable to splinters entering the windows from front and back. It would be a good thing to block the kitchen window or, even better, to make a screen wall to cover the back door, kitchen window and w.c. door

FIG. 41.—Plans of typical houses showing refuge rooms.

will often preclude its use in the average household. The following simple fire precautions can be taken in the home at very small expense and will add greatly to the protection of the household during incendiary attacks:

1. Make sure that each member of the family knows the emergency fire-fighting arrangements for the neighborhood, where the nearest fire station or fire patrol is established, and how to call the local Warden and to summon the regular city fire department if all other measures fail.

2. Clear the loft, attic, or top floor of the house of all inflammable material, such as "junk," paper, litter, and lumber, in order to reduce the danger of fire and to prevent its spread.

3. Arrange a sure and quick means of entry into the attic or roof space. If the only entrance is through a trap door, see that a ladder is kept on hand at all times.

4. For controlling an incendiary bomb, it is desirable to have on hand at a convenient place in the top story of the house at least four large buckets, a long-handled scoop or shovel, and several bucketfuls of dry earth or sand in a box.

5. As water is the best means of putting out a fire started by an incendiary bomb, at least two buckets should be kept filled with water near the attic entrance. These should be supplemented wherever possible by a stirrup hand pump, as described in Chap. X, or a garden hose long enough to reach from the nearest water tap to the attic.

6. The inside of the loft, attic, or top story of the house should be rendered more fire resistant by coating all woodwork with two coats of whitewash consisting of 2 lb. of slaked lime, 1 oz. of common salt, and 1 pt. of cold water.

7. The floor of the loft, attic, or top story of the house should be protected by covering it with sheets of corrugated or plain iron (22 gauge or thicker) or asbestos wallboard or with 2 in. of dry sand. As the sand will considerably increase the weight on the floor, it should not be used until advice is obtained from the local authorities as to whether the floor is strong enough to bear the extra load and, if not, how it should be propped up for the purpose.

Lighting Restrictions.—The general wartime restrictions against lights visible at night apply to private dwellings as well as to all other buildings in a darkened area. It is therefore essential that steps be taken completely to screen all windows, transoms, skylights, glass doors, and other outside openings of the house where lights are used, so that no light is visible from outside. This may be done by completely covering all openings with blinds made of stout material of dark color. Curtains may be used if they are dark and thick; blankets, carpets, or thick sheets of brown paper will also serve satisfactorily for temporary covers. All lights near an outside door must be screened so as not to be visible from outside when the door is open, and of course all exterior lights must be extinguished. As the restriction on lights will be rigidly enforced in time of war, it is essential that the work of darkening a house and screening all lights be carefully performed so as completely to meet the official requirements.

Gas Masks.—As gas attacks may be delivered with great suddenness and disastrous effects upon the civil population, unless it is prepared for such an eventuality, it is imperative that every man, woman, and child have a properly fitting gas mask. When an emergency becomes imminent, the national Government will see to it that the civil population is supplied with gas masks, either at government expense, as in England, or at the individual's expense, as in other European countries.

The type of mask issued generally to the civil population (exclusive of ARP workers) is known as the "civilian mask" and is intended to afford the required protection at the minimum expense (see Chap. VI, page 136). When masks are issued to the civil population, they will be properly fitted under the supervision of the local Air Raid Warden and other representatives of the local authorities and each individual will be instructed how to adjust and use the mask and how to take proper care of it. Gas masks for members of a household should be considered as a second line of defense, to be used indoors only when gas has penetrated into the refuge room, which is the first line of gas defense for the home. It is, however, necessary that each member of the household have a mask in case of accidental leakage of gas into the refuge room or in the event that windows or doors are blown open by bomb damage so that gas may enter. Masks are also necessary in case citizens are caught in a gas attack while in the streets. Protective clothing as described on page 144 may be issued to civilians, if vesicant sprays on bombs are used in hostile air attacks.

Equipment for a Refuge Room.—When the Government indicates that a threat of war is imminent, the following articles should be collected for use in a family refuge room:

Tables and chairs.
Supply of water, for drinking, washing, and fire fighting.
Books, cards, writing materials, and toys for children.
Four large fire buckets.
A stirrup hand pump.
A box of sand and a long-handled shovel.
Gummed paper and pots of paste or gum for pasting paper over cracks and windowpanes.
A first aid kit.
China and cutlery.
Canned food, with can opener.
A food chest with airtight containers to protect food against gas.
Chamber pots, toilet paper, disinfectant, and a screen for privacy.
Spare blankets or rugs for resealing windows if they should be blown in.
Pickax and shovel to clear fallen debris.
Electric grill for cooking and heating.
One or two flashlights, matches.

In addition to the foregoing, the following articles should also be taken into the refuge room when an air raid warning is received:

Mattresses.
Overcoats.
Radio set.
Blankets.
Rugs and warm coverings.
Raincoats, rubbers, and gum boots.

Importance of Cover.—From what has been said in Chap. II about the effects of various kinds of bombs and gas and in Chaps. IV, V, and VI concerning the means and methods of protection against these dangers, the importance of habitually taking cover during air raids should be obvious. This matter cannot be too strongly emphasized, in view of the tendency of the average citizen to remain in the street or at a window to watch what is going on during an air attack. In addition to the danger of injury from hostile bombs and gas, there is also the peril of being struck by fragments of antiaircraft shells which may fall many miles from the scene of action. Again, it must be remembered that bombs are released from modern aircraft several miles before they are over the target area (see page 21); hence, a person watching an air raid at some distance away may find himself suddenly and without warning in the midst of falling bombs.

Recent experience in England has shown that air raid casualties among the civil population are in almost direct proportion to the extent to which the people fail to take cover and expose themselves during air attacks. Thus, if the danger of injury by high explosive bombs from standing in a street during an air raid be rated as 100 per cent, merely lying down in the street reduces this danger to 50 per cent; lying down behind low cover or in a doorway reduces the danger to 33 per cent; sheltering in a house or other place affording head and side cover away from windows reduces the danger to 11 per cent; and taking cover in a shelter of the Anderson type, a covered trench, a surface shelter, or a basement with reinforced ceiling, all measuring up to the standards of protection mentioned in Chap. IV, reduces the danger to about 4.5 per cent. In other words, a person taking shelter in a house affording head and side cover away from windows runs 2½ times the risk of injury from high explosive bombs as a person in a standard shelter of any of the types mentioned; one lying down behind low cover or in a doorway runs 7½ times the risk of injury; one lying down in the street runs 11 times the risk of injury; and one standing in the street runs 22½ times the risk of injury.

It is accordingly obvious that when an air raid warning is heard, no time should be lost in finding the nearest shelter. Persons in or near their own homes should repair at once to their refuge rooms, and employees at their places of business should take cover in the shelter provided by their employers. Those caught in the streets should not attempt to go home unless they can get there within 5 min. but should seek the nearest public shelter. If no public shelter is near by, they should take the best cover they can find in doorways, behind walls, in ditches, or even lying down in the open.

Persons who are indoors when an air raid alarm is sounded, even where no refuge room is available, should remain on the premises and not try to make their way to a public shelter, since it is much safer to remain in an unprotected house than to be caught in the streets when bombs are falling. If bombs are bursting near by, the ears should be stuffed with cotton and the mouth kept open by gripping a piece of wood or rubber tightly between the teeth. During an air raid, as in all emergencies, the first necessity is to keep cool and act swiftly in accordance with the advice and instructions issued by the Government and local authorities and to avoid taking unnecessary risks.

After all is said and done, the success of the Civil Air Defense of a community and the ability of the people to withstand the devastating effects of air attacks will largely depend upon the foresight and behavior of the individual householder and the family in the home. The various measures for protecting the civil population are but a means to an end. The end is the maintenance of the public morale and the will of the people to carry on their daily tasks despite the utmost that the enemy can do to break this morale and dislocate the life of the community. Perhaps the greatest single factor in attaining this end is the wholehearted and intelligent cooperation of the individual with the Government, which begins at home.

CHAPTER XVIII

OTHER MEASURES OF CIVIL AIR DEFENSE

General.—Having completed a survey of the field of air raid precautions, we shall briefly consider the other broad aspects of the protection of the civil population against air attack, in order to complete the picture of Civil Air Defense.

The principal measures of protection, other than air raid precautions, are

1. Evacuation.
2. Dispersion.
3. Segregation.
4. Concealment from air observation.
5. Care of refugees.
6. Planning for the future.

Each of these subjects will now be briefly considered in turn.

Evacuation.—Since the large cities not only contain the greatest density of population and manufacturing industries but are also, generally speaking, the nerve centers of the economic life of the country as well, it is obvious that they are by long odds the most probable targets for hostile air attack; and this is true no matter what a belligerent state's theory of war may be. If the aggressor state holds to the Douhet doctrine of direct action against the enemy's civil population, in order to break its morale and compel its Government to sue for peace, it will direct its effort against the large centers of population, *i.e.*, the great cities. If the aggressor state, on the other hand, aims at the destruction of its opponent's munitions industry, in order to paralyze military effort, it will also concentrate its air attacks against its opponent's great cities where the munitions industries are largely congregated. Again, if the aggressor state's theory of war places principal emphasis on the dislocation of the economic life of the opposing state, in order to bring about its subjugation, it will still give first priority to air attacks upon the enemy's great cities, which largely control economic life. And so it appears that regardless of which theory of war is adopted by belligerent states, each will exert its main air effort against the other's principal cities. Recent war experience in Europe seems fully to substantiate this view.

If, then, the large cities are the principal danger areas, from the viewpoint of air attack, it follows that the civil population should, to the maximum extent practicable, be evacuated from the cities into the country. Though evacuation is simple in principle, its practical application is attended with many complex problems. Theoretically, the ideal objective of evacuation is to remove from the cities to the country all those elements of the urban population which are not essential to the national defense or the economic life of the nation. In other words, every person in the city should be evacuated unless he has some vital reason to remain from the Government's viewpoint.

Though such a drastic policy could probably never be fully carried out, because of the difficulty of executing and enforcing it and its adverse effect upon the public morale, there are undoubtedly certain categories of persons who should obviously be evacuated immediately upon the outbreak of an emergency, such as children, the aged and infirm, and unemployables generally. If the situation becomes more serious, evacuation should be extended to unemployed women and all those who have no cogent reason for remaining in the city.

The first problem in connection with the evacuation of a city is, then, the determination of *who will go*. This matter should be worked out by the local authorities in each community, in accordance with the national Government's policy. The whole population should be divided into categories, in order of priority of evacuation, consideration being given to the relative danger of the different areas of the city and to the economic value to the city of persons in each category. Thus, a reasonable order of evacuation would be as follows:

1. Children of school age (with their teachers) from the entire city.
2. Inmates of institutions for the aged, infirm, incurables, insane, indigent, etc.
3. Mothers, babies, and old people from the most dangerous areas of the city.
4. Mothers, babies, and old people from less dangerous areas of the city.

5. Unemployable people of all kinds.

6. Those not required to carry on the usual industrial and commercial life of the city.

7. Those not engaged in industries essential to the national defense, considered broadly as including the economic value of the city to the national defense.

8. Those absolutely essential to carry on vital industries during a state of siege, without regard to personal safety.

The definition of the several categories and the order of evacuation should be prescribed by national Government edict; the classification by categories of individuals in the community and the fixing of areas of relative danger should be left to local boards acting under the aegis of the state and the municipal authorities.

The determination of what cities and towns are to be evacuated is a matter for decision of the national Government, though the places to which the evacuees are sent may be determined by the state and local authorities, within certain areas determined by the national Government.

The question of whether evacuation is to be voluntary or mandatory is also one of national policy and depends largely upon the situation in each case. In principle, voluntary is far preferable to mandatory evacuation, provided that it will give the desired results. This can be determined only by actual experience; but voluntary evacuation should certainly be tried initially, at least as to certain categories, in order to see what results are produced, before resort is had to forced evacuation. With regard to the first and second categories, mentioned above, there should be no option, and these classes should unquestionably be evacuated immediately upon the outbreak of an emergency. Complete and detailed plans should be made for this purpose in time of peace, for those cities likely to be subject to air attack in time of war, so that no time is lost in evacuating these classes when the emergency is imminent.

It is doubtful if complete and detailed plans can be made in time of peace for the other categories, mentioned above, since it is almost impossible to estimate the numbers and classes involved, unless their evacuation is made mandatory. Nevertheless, *general* plans should be drawn up for the evacuation of these categories when and if the situation requires, although they would probably not be removed until after the outbreak of the emergency and if it clearly became necessary.

After it has been determined who will go, the next question for consideration in the evacuation of a city is: *How will the evacuees go?* This is a complicated problem of logistics, albeit the forces involved are civilian and not military; it depends primarily upon the capacity of the various means of transport to deal with the situation. It is probable that all types of transport locally available will have to be impressed in order to move the many thousands involved in evacuating even the initial categories in each large city. Main reliance will be placed upon suburban railroads, electric lines, motor coaches and busses, and private motor transportation of all kinds.

Movement tables, showing where and when each movement of each group starts, the route it takes, its destination, the type and number of trains or vehicles involved, and the numbers moved, must be prepared in advance and carefully coordinated as to time and space factors, so as to avoid interference between the various movements. The local authorities in each city are responsible for the preparation of these movement tables, as an integral part of the evacuation plan, and they will, undoubtedly, call in the traffic experts of the various railroads and transportation companies to assist them in this work.

It is probable that the average haul in each case will vary between 50 and 100 miles from the city. A distance of less than 50 miles would hardly be safe, and distances greater than 100 miles are unnecessary, except in unusual situations. It is desirable that the evacuation be carried out by a single outbound trip; but this may not be possible in all cases, owing to insufficient transport, and it may then become necessary to resort to shuttle moves.

The next question in formulating an evacuation plan is: *Where will the evacuees go?* This can best be determined by a survey and careful study of the facilities of the countryside within the area to which the evacuation will be made. As stated above, it is probable that the evacuees from each city will be accommodated within an area surrounding the city of 50 to 100 miles radius. A survey of this area will indicate what housing accommodations already exist, and these must be supplemented by camps or cantonments with sufficient accommodations for those who cannot be housed in existing farms and villages.

These camps and cantonments must include facilities for feeding and maintaining the evacuees assigned and also means for schooling the children and for other necessities of communal life, all of which must be, of course, supplied at government expense, either national, state, or local. Plans for the construction and operation of these camps and cantonments, as well as for the maintenance of the evacuees in existing shelter in the country, form a part of the evacuation plan.

An evacuation plan must, accordingly, prescribe: (1) who is to be evacuated; (2) how they are to go; (3) where they are to go; and (4) how they are to be housed and maintained in the evacuation area. Since these plans are naturally very voluminous and must be prepared in great detail, they should be carefully coordinated in their various parts, so that there will be no confusion or uncertainty in their execution when the time arrives to put them into effect.

Dispersion.—In connection with Civil Air Defense, "dispersion" refers to the scattering of persons and installations over a vulnerable area, as opposed to concentrating them at one point. Dispersion is thus quite different from evacuation; for, in the former, the persons remain in the vulnerable area, whereas, in the latter, they are entirely removed to an area that is considered safer from air attack.

With regard to personnel, there is a considerable difference of opinion as to the value of dispersion as a means of protection against air attack. Thus, one school of thought holds that scattering people in small groups throughout a vulnerable area will automatically lessen the danger of their injury by bombs, since no bomb can reach more than a few persons, regardless of where it strikes. On the other hand, the second school of thought maintains that dispersion within a dangerous area cannot possibly reduce the probable number of casualities, since, though ensuring that no single bomb will wipe out 100 people in one place, it also ensures that almost every bomb will find a human target of some kind.* In other words, though dispersion reduces the numbers affected by any one bomb, it correspondingly increases the probability of each bomb striking some persons, so that the net advantage is nil.

This second view is undoubtedly valid from a purely mathematical point of view, but there are many other factors of a practical nature that enter into this question and appreciably modify theoretical results. Thus, the opponents of dispersion apparently assume that the injurious effects of high explosive bombs are due solely to the destructive action of blast and splinters. If this were the case, then dispersion would make no difference in the number of casualties resulting from the bombardment of a given area, other things being equal. However, it is well established that casualties in air raids are caused by many things other than bomb blast and splinters, notably falling buildings and flying debris. This being the case, the nature of the buildings in which persons are sheltered has much to do with their liability to injury during an air raid. In general, multistory masonry buildings are more dangerous to occupants than even light frame buildings, such as two-story cottages, for the falling walls and flying debris of the former will cause casualties in addition to bomb blast and splinters, whereas, in a light frame house, there are no masonry walls to fall and flying pieces of masonry to strike the occupants.

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* This is the view expressed by Dr. J. B. S. Haldane in his recent book "A.R.P," p. 125, Victor Gollancz, Ltd., London, 1938.

And so the question of whether school children occupying a multistory school building should be sent home to frame cottages during an air raid is not solely a matter of dispersion, but rather one involving a difference in the character of the building and its effect upon the occupants when a bomb strikes within destructive range.

Of course, if all the buildings in a danger area react with equal injurious effect upon their occupants, when subject to bomb explosions, it would make no difference whether the people in the area were congregated in one building or scattered in several, except for the moral effects, where the advantage is in favor of disperson, since undoubtedly the psychological effect of 10 persons being killed by bombs in 10 different places in a city would be less than that of 100 persons being killed by 1 bomb.

Moreover, since buildings vary considerably in their protective value, and it is easier to devise equal protection at home than in the average public building, except of the modern frame type, there is some protective value in dispersion of the population in a danger area, though undoubtedly its efficacy has been greatly overrated.

With respect to the dispersion of factories and other commercial establishments, without question the advantages are all in favor of dispersion. For by scattering the activities of a manufacturing plant over an area, not only is the destructive effect of bomb damage limited, but it is possible better to conceal the plant from air observation and to make it a far less conspicuous and favorable target for hostile bombers.

By dividing the manufacturing operations among a number of scattered buildings, instead of concentrating them in one large building, small single-story structures can be used, which eliminates the dangers of falling masonry walls and flying debris. Also, though many small buildings will increase the number of fires from incendiary bombs, these fires will be localized and much easier to extinguish before they do material damage than is the case where a fire is started in the top floor of a large multistory building. And so there is no question but that dispersion materially increases the protection of manufacturing and commercial establishments from air attack.

Segregation.—Where factories have to handle explosives, highly inflammable liquids, or other hazardous materials, it is safer for the establishment as a whole if these dangerous materials and operations are grouped together and placed at a distance from other buildings in the plant and surrounding neighborhood. This is known as "segregation" and should be standard procedure in all manufacturing and commercial establishments in areas vulnerable to air attack.

Thus, powder and ammunition loading plants, oil refineries and storage depots, and magazines and storehouses for inflammable stores should be separated by a safe distance from all other buildings in the surrounding area and should never be located within the boundaries of cities when it can possibly be avoided. All such buildings should be situated well outside the city and should be spaced safe distances apart and concealed from air observation.

It is also desirable to segregate business and commercial activities in a city as much as possible in special zones or areas safely removed from residential districts; for the former constitute more profitable and likely targets for hostile air attack than the latter, and segregating helps to keep bombing attacks away from residential districts.

Concealment.—Concealing important buildings and activities from air observation is one of the most valuable means of protection against air attack, provided that they are segregated and are located at a safe distance from other unconcealed targets.

Aside from lighting restrictions which have been previously described, the principal means of concealment are:

1. By location underground or beneath natural cover, such as trees and vegetation.
2. By camouflage.

Except for the great expense involved, the *location* of a building or activity *underground* not only affords maximum protection against bomb damage but is the most effective form of concealment. In seeking to protect especially important vital activities, consideration should always be given to placing them underground, even though the depth to which it is practicable to go is less than that required for full overhead protection. Where the terrain is hilly, it is frequently possible to drive tunnels and horizontal galleries into the sides of hills at far less expense than that of excavating underground, and the protection secured is equally effective. Where underground construction is precluded on account of the cost or for other reasons, *locations under natural cover* should be sought. Wooded areas are the best form of natural cover; where these are not available, areas covered with underbrush and other vegetation are to be preferred to denuded ground.

When natural cover cannot be found, it is highly desirable that steps be taken to conceal all important installations from aerial observation by *camouflage.* The purpose of camouflage is, of course, to render an object as inconspicuous as possible when viewed from the air. Since the visibility from the air of an object on the ground arises out of differences in color, tone, light, and shade, as compared with its background, any measure that reduces these differences results in rendering the object less conspicuous and therefore less recognizable through aerial observation. This is the object of camouflage.

In camouflaging an object, the following fundamental principles are involved:*

1. Shadow elimination.
2. Countershading.
3. Color resemblance.
4. Deceptive coloration.

Shadows may be eliminated by properly orienting the building so as to reduce the contrast between the lighted and shaded portions, as the sun changes its position during the day. Another method of eliminating shadow is to apply sheets of canvas to the sides of the building, with a slope of 15° to 30° to the horizontal. Shadows may also be disguised by the use of camouflage netting of bright color arranged to confuse vision through it. Another method of camouflage is the distortion of shadows to shapes appropriate to the surroundings.

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* GLOVER, C. W., "Civil Defense," 2d ed., p. 556, Chapman & Hall, Ltd., London, 1940.

Countershading is another means of camouflage whereby a surface in relief is made to appear flat. This deception is achieved by darkening the high lights and lightening the shadows, so as to reduce the light and shade contrasts that disclose the form and contours of the surface.

Painting objects in irregular patterns with colors that make them blend with surrounding objects is one of the most effective forms of camouflage and is quite inexpensive to apply. Still another scheme is to superimpose a pattern of bright contrasting colors so as to distract attention and conceal the true outline of the object.

The art of camouflage was highly developed during the World War, with respect to concealment of objects on the field of battle. Since the War, it has been still further perfected and applied to the concealment of buildings and ground activities of all kinds from aerial observation and photographic detection. The value of camouflage in concealing installations built on open ground is now so well established that no important plant should be constructed in an area vulnerable to air attack without utilizing the various methods to the maximum extent.

Care of Refugees.—When the residential area of a city is subjected to air bombardment, many houses will be destroyed and the occupants who are not killed or injured will be rendered homeless. As considerable time is required to replace houses destroyed by bomb damage, the number of homeless citizens will increase with the progress of the war and will soon reach considerable numbers. Of course, those who have no adequate reason to remain in the city should be encouraged and, if necessary, even ordered to evacuate to the country. However, many of these refugees are needed to carry on essential industries and should not be evacuated. Hence, it is necessary that some provision be made by the local authorities for taking care of those whose homes have been destroyed until suitable housing can be found for them.

The arrangements for caring for homeless refugees is an important part of the Civil Air Defense plan of a community and should be carefully worked out before the occurrence of an emergency. One of the first steps is to survey and list all vacant houses and other buildings that can be utilized for housing purposes in the city and to allocate these vacant premises to each Warden's district on an equitable basis.

As vacant housing will usually be inadequate to accommodate all the refugees that will accumulate in a large city, it is necessary to plan for the erection of temporary buildings to serve as communal dwellings during the emergency. These buildings should be designed to house a unit of about 100 individuals with complete central messing and laundering facilities.

Not the least among the problems of caring for refugees made homeless by bomb damage is the matter of providing mobile soup kitchens and other facilities for feeding these people until they can be allocated to available shelter. This is essentially a public relief problem, in which the relief agencies of the national and local governments and private organizations, such as the American Red Cross Society, should cooperate and work together under the direction of the local authorities.

Another problem demanding careful attention is the maintenance of sanitary conditions in crowded public shelters and communal dwelling houses. Unless special precautions are taken, epidemic diseases may spread rapidly among the population and assume serious proportions, at a time when medical and hospital facilities are taxed to the limit in caring for air raid casualties. To prevent such catastrophies, the emergency Civil Air Defense agencies charged with this responsibility should work hand and glove with the national and local public health authorities and make such provision as is necessary to maintain sanitary conditions and safeguard the public health in devastated areas during the emergency.

Higher Civil Air Defense Organization.—The measures discussed in this chapter are all vitally necessary to the protection of the civil population against air attack and, properly speaking, fall outside the province of the Air Raid Precautions Department (ARPD). It is therefore necessary to set up an organization in each community to deal with these problems and to coordinate such activities with those of the ARPD.

For this purpose, the mayor of each city should appoint a prominent businessman of outstanding executive ability and reputation in the community, as Director of Civil Air Defense, with authority to supervise and coordinate all the activities within the city having to do with the protection of the civil population against air attack in its broadest aspects.

The Director of Civil Air Defense reports direct to the mayor and is coordinate with the heads of the other major departments of the city government. He supervises and coordinates the work of the following agencies of Civil Air Defense:

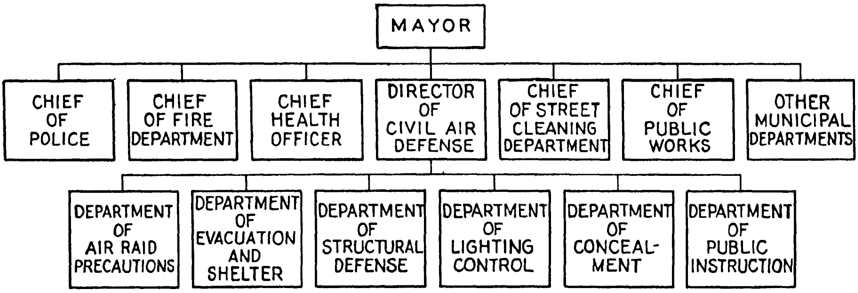
MAYOR
CHIEF OF POLICE
CHIEF OF FIRE DEPARTMENT
CHIEF HEALTH OFFICER
DIRECTOR OF CIVIL AIR DEFENSE
CHIEF OF STREET CLEANING DEPARTMENT
CHIEF OF PUBLIC WORKS
OTHER MUNICIPAL DEPARTMENTS
DEPARTMENT OF AIR RAID PRECAUTIONS
DEPARTMENT OF EVACUATION AND SHELTER
DEPARTMENT OF STRUCTURAL DEFENSE
DEPARTMENT OF LIGHTING CONTROL
DEPARTMENT OF CONCEALMENT
DEPARTMENT OF PUBLIC INSTRUCTION

Fig. 42.—Municipal organization for civil air defense.

1. Air Raid Precautions Department.
2. Department of Evacuation and Shelter.
3. Department of Structural Defense.
4. Department of Lighting Control.
5. Department of Concealment.
6. Department of Public Instruction.

(See Figure 42)

The work of the *ARPD* is described in Chaps. VIII to XV.

The *Department of Evacuation and Shelter* plans and supervises the evacuation of citizens from those areas from which it is necessary to remove them, because of danger to life and limb and as a matter of public policy. It also plans and supervises the location and construction of public shelters and communal dwellings for homeless refugees and handles all matters in connection with extending relief to refugees and relocating them in temporary shelter until such time as they can be evacuated or returned to their homes.

The *Department of Structural Defense* plans and supervises the execution of all measures for strengthening existing public buildings and utilities, so as to make them more resistant to air bombardment. It also inspects private buildings and utilities, including hotels, apartments, and individual dwellings, and advises as to how these buildings can be improved in their resistance to bombardment. It approves all new construction, both public and private, before permission is granted by the local authorities for its erection.

The *Department of Lighting Control* plans and supervises the execution of all measures of restriction of lights at night, including blackouts of designated areas, the extinction or shading of essential street lights, and the concealment of all lights in buildings from visual observation outside. It also arranges for the regulation of all traffic moving at night and decides what shaded lights and other aids are to be permitted. Its authority in this matter extends to the control of lights on all public and private vehicles, including common carriers operating within the area of its jurisdiction.

The *Department of Concealment* plans and supervises the execution of all measures for concealing buildings and activities from air observation, including dispersion, location with reference to natural cover, underground construction, camouflage, etc. Its authority extends to all public and public service buildings and utilities. As to private buildings and utilities, its action is advisory only except as to those phases of the matter which are clothed with a public interest, in which case it has authority to inspect private premises and enforce its rules and regulations.

The *Department of Public Instruction* is charged with all measures having to do with the enlightenment and education of the public in air raid precautions and other matters pertaining to Civil Air Defense. It operates its own schools for the training of instructors who, when graduated, are sent out to indoctrinate the people in all phases of protection against air attack. It also prepares all press releases, articles and instructions to the public, and such general pamphlets and technical information as are required for public information.

From what has been said above, it may be seen how far-reaching is the scope and character of the activities that have to do with Civil Air Defense. Indeed, it is probably no exaggeration to say that upon the outbreak of war, the Director of Civil Air Defense becomes the dominant authority in the community, second only to the mayor, in all areas vulnerable to hostile air attack. He is charged with providing for the safety and welfare of every citizen in the community under the most difficult conditions. He should, therefore, be clothed with full authority to take such steps as are necessary to carry out his responsibilities and should have the wholehearted support and cooperation of not only the other departments of the city government and private industry but also the man in the street and every individual householder.

Planning for the Future.—There is probably no development in modern times that seems destined to exert such a profound influence on our civilization of today as the advent of air power as a major instrument of war. It has already caused a complete reorientation of the national defense establishments of all the leading world powers, but this is only the beginning of its foreseeable effects upon modern life.

The necessity for bomb-proofing, fireproofing, and gas-proofing of all buildings and utilities from the city hall to the humblest home will bring about a complete revolution in the conventional principles of engineering design and construction. The shock effect of high explosive bombs produces a far greater strain upon all elements of a structure than the most severe live or impact loads with which engineers have been familiar in the past. Thus all formulas involving stress and strain, which constitute the foundation of engineering design, must undergo complete revision to take into account these new factors.

At the same time, the enormously destructive effect of incendiary bombs demands a vigorous development in fireproof building materials and methods of construction, if this new threat is to be successfully met. The so-called "fireproof" buildings of today have proved wholly incapable of resisting the onslaught of incendiary bombs, and far-reaching improvements in this direction are imperative if the cities of the future are to be saved from destruction by fire.

The same is true with respect to the protection of the civil population from toxic gas. Though gas has not as yet been used against the cities, we know from World War experience what to expect in case of such an eventuality. The casualty-producing power of gas is, pound for pound, manyfold greater than that of the most powerful explosives, chiefly because of its greater coverage in area and the small amount of gas required to incapacitate a person.

Although the development of gas masks and protective clothing since the World War has been impressive, it has by no means solved the problem of protection against even certain of the well-known World War gases, such as mustard and lewisite. Thus, it is wholly impracticable to put the whole civil population in impermeable anti-gas suits which can be worn only for 2 or 3 hr. without exhaustion. And so we must find a better means of protection against vesicant gases already known, to say nothing of new and more powerful gases that may be used in the future.

The methods of collective protection against gas will also have to be applied to all new buildings where important activities must be carried on during prolonged gas attacks. Here the modern art of air conditioning will lend a helping hand; for once buildings are equipped for air conditioning, it will be a simple matter to add chemical filters to purify the incoming air of toxic gas.

More far-reaching than the design and construction of buildings will be the changes necessary in city planning in the future. The first step will be to remove essential industrial plants and vital public service utilities from the cities and to disperse them at safe distances in the rural areas outside the areas they serve. The net result of this process will be to reverse the trend toward the building up of large urban communities which was started in the nineteenth century by the Industrial Revolution. The tremendous development of motor transportation during the past three decades has already made the congestion of population in large cities unnecessary, and it is now no longer essential to locate factories in cities in order to be near the labor market. With the imperative necessity of removing large industries from the great cities, brought about by the danger of air attack to the whole surrounding population, we may expect to see an increasing trend toward decentralization of industries to rural areas and small communities.

For those activities which must remain in the city as an organic part of its life, segregation must be rigorously applied, so that all plants and instrumentalities that have any value as military objectives for air attack will be located in allotted zones and parts of the city at a safe distance from the residential areas. In this way, there will be no excuse for indiscriminate bombardment of the civil population, or even for negligently or unavoidably involving it in bombardments of military objectives. Under such conditions, any bombing of the civil population will clearly be deliberate, with a view to breaking its morale, so that the Government will be compelled to sue for peace, even though the military forces of the country are still unconquered.

Whether this method of waging war will be any more successful in the future than it has been in the past would appear to depend largely upon the degree to which the civil population is prepared to resist such attacks. With a well-organized Civil Air Defense, it is more than likely that deliberate bombing of the civil population alone will never win a decision in war. On the contrary, it is more apt to have the opposite effect and serve to steel the nerves of the people and increase their will to see the war through to a successful conclusion at all costs.

On the other hand, if the Civil Air Defense is inadequate and the people lose confidence in the ability of their Government to meet the threat of modern air warfare, it is entirely possible that a war may be lost by a failure of the home front, despite the successes that may have crowned a nation's military effort.

With the issues thus defined, it is unnecessary further to emphasize the importance of Civil Air Defense to the future security of our country.

APPENDIX

BRITISH OFFICIAL CODE GOVERNING CONSTRUCTION OF AIR RAID SHELTER

STATUTORY RULES AND ORDERS

1939 No. 920

CIVIL DEFENCE

The Civil Defence (Approval and Revision of Code) Order, 1939 Dated 14th August, 1939, made by the Lord Privy Seal under section 13 of the Civil Defence Act, 1939 (2 & 3 Geo. 6 c. 31)

Whereas a Code for the guidance of occupiers and owners of factories, commercial buildings, and other persons concerned in providing air-raid shelter, was issued before the commencement of the Civil Defence Act, 1939 (a), and published by His Majesty's Stationery Office under the title "Air-raid Shelters for Persons Working in Factories and Commercial Buildings":

And Whereas it is expedient that the requirements prescribed in the said Code should have effect in relation to shelter provided before the date of this Order:

Now, therefore, I, in pursuance of the power conferred on me by section 13 of the Civil Defence Act, 1939 (*a*), hereby by this Order approve the said Code for the purposes of the said Act:

And Whereas it is expedient that the said Code should be revised:

Now, therefore, I, in pursuance of the power conferred on me by the said section, hereby further order that the said Code be revised by such revocation and variation of and addition to its provisions as are necessary to bring the said Code into conformity with the revised Code set out in the Schedule hereto.

And I hereby further order that the Interpretation Act, 1889 (*b*), shall apply to the interpretation of this Order as it applies to the interpretation of an Act of Parliament, and that this Order may be cited as the Civil Defence (Approval and Revision of Code) Order, 1939.

JOHN ANDERSON,
Lord Privy Seal.

WHITEHALL,
14*th August*, 1939.

SCHEDULE

Revised Code (Section 13 of the Civil Defence Act, 1939) for the Guidance of Occupiers and Owners of Factory Premises, Factories, Mines and Commercial Buildings, and Other Persons Concerned

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[a] 2 & 3 Geo. 6. c. 31.

[b] 52 & 53 Vict. c. 63.

PART I

REQUIREMENTS WITH WHICH SHELTER MUST COMPLY

1. Definitions.—For the purposes of this Code the following expressions shall have the meanings hereby respectively assigned to them:

"Air-Raid Shelter" means protection otherwise than by war-like means or by any article of apparel, from hostile attack from the air, and "an air-raid shelter" means any premises, structure or excavation used or intended to be used to provide air-raid shelter.

"Trench shelter" means an air raid shelter in the form of a covered trench or tunnel which, where above or partly above ground level, is covered with earth to a thickness of at least 12 inches at every part.

"Accommodation" relates to the number of persons to be accommodated in an air-raid shelter or in any section or compartment thereof.

"Prescribed stresses" shall mean the maximum permissible working stresses specified.

(*a*) in respect of reinforced concrete, in the "Recommendations for a Code of Practice for the use of Reinforced Concrete in Buildings" of the Reinforced Concrete Structures Committee of the Building Research Board,

(*b*) in respect of steel, in British Standard Specification No. 449–1937 ("The Use of Structural Steelwork in Buildings"),

(*c*) in respect of pressures on load-bearing concrete and masonry (brick and stone), in "Notes on the Use of Materials and Construction in Connection with Steel Structures" appended to B.S.S. 449–1937,

(*d*) in respect of timber, in "By-laws for the Use of Timber" made by the London County Council on the 30th November, 1937.

"Sound brickwork" means brickwork consisting of sound, well-fired clay bricks, sand-lime bricks complying with the requirements of British Standard Specification 187–1934 for building bricks Class A, or cement concrete bricks having a crushing strength of not less than 1,500 lb. per sq. in. when rested in accordance with the methods laid down in the second schedule of Ministry of Health, Model Byelaws, Series IV, Buildings 1937, properly bonded and jointed in mortar which is properly set and hardened.

"Brickwork in cement mortar" means brickwork consisting of bricks as described above for sound brickwork, properly bonded and jointed in cement mortar not weaker than one volume of cement to three volumes of sand, or in cement lime mortar not weaker than two volumes of cement, to one of lime to nine of sand.

"Sound stonework" means coursed natural or cast stone masonry in sound condition.

"Ordinary concrete" means concrete mixed in the proportion of not less than 112 lb. of cement complying with the requirements of British Standard Specification No. 12–1931 or of British Standard Specification No. 146–1932 to 12 cubic feet of suitable coarse and fine aggregate measured as combined.

"Structural concrete" means concrete of a quality permissible under the recommended Code of Practice for the use of Reinforced Concrete in Buildings of the Reinforced Concrete Structures Committee of the Building Research Board, consisting of not less than 112 lb. of cement, complying with the requirements of British Standard Specification No. 12–1931 or of British Standard Specification No. 146–1932 to 2½ cubic feet of suitable fine aggregate and 5 cubic feet of suitable coarse aggregate.

"Reinforced concrete" means structural concrete as described above, reinforced in accordance with the Code of Practice, such reinforcement amounting in each cubic foot of concrete to not less than 2 lb. of steel total (exclusive of laps and hooks), suitably distributed in the concrete, of which total at least 0.7 lb. is distribution steel at right angles to the main steel.

2. Lateral and overhead protection.—An air-raid shelter must be of such construction as to give

(*a*) Lateral protection by means of not less than:

(i) 1½ in. thickness of mild steel plate or plates,
(ii) 12 in. thickness of reinforced concrete,
(iii) 13½ in. thickness of sound brickwork or sound stonework,
(iv) 15 in. thickness of ordinary or structural concrete, unreinforced,
(v) 2 ft. thickness of ballast or broken stone,
(vi) 2 ft. 6 in. thickness of earth or sand, or
(vii) a corresponding aggregate thickness of a proportionate combination of such materials.

and

(*b*) Overhead protection, subject to the requirements of paragraph 3 for protection from falling debris, by means of not less than:

(i) ¼ in. thickness of mild steel plate,
(ii) 4 in. thickness of structural concrete reinforced if and as necessary or otherwise suitably strengthened or effectively supported,
(iii) 6 in. thickness of ordinary concrete, reinforced if and as necessary or otherwise suitably strengthened or effectively supported,
(iv) concrete in hollow type construction conforming with the requirements set out in the Appendix to Part I of this code,
(v) 8½ in. thickness of arching in sound brickwork or sound stonework.
(vi) 1 ft. 6 in. thickness of ballast, broken stone or earth,
(vii) a corresponding aggregate thickness of a proportionate combination of such materials, or
(viii) a substantial building overhead consisting of a roof and not less than two floors (including that covering the shelter) where such structure is enclosed with walls of brick, stone or concrete.

Provided that, subject to the approval of the Minister, other materials, of such thickness as he may prescribe, may be used to give protection.

In the case of an external air-raid shelter wholly or partly above ground, the material affording overhead protection must be such as to be a dead weight of not less than 60 lb. per sq. ft. of horizontal area or must be so fastened down as to resist an upward force of 300 lb. per sq. ft. of horizontal internal surface.

The lateral protection must extend throughout the height of the air-raid shelter and similarly the overhead protection must extend over the whole area of the air-raid shelter.

Provided that in the case of an air-raid shelter wholly above ground where the aggregate area of door and window openings in any one wall of a shelter compartment does not exceed one-quarter the surface area of such wall and the total width of such openings does not exceed one-third the total length of such wall, it shall suffice if the protection in such openings extend to a height of 6 feet above the floor of the air-raid shelter, subject to movable protection being provided to the space above, such protection consisting of timber shutters not less than 2 inches thick or mild steel shutters not less than 3/16 inch thick or other approved material or it shall suffice if the openings are protected by a screen wall or walls giving the lateral protection required under section (2) above, situated not more than 12 feet from the face of the wall of the shelter and extending beyond such openings for a distance sufficient to prevent the entrance of splinters. This requirement will be deemed to be complied with where the extent of such screen beyond the opening is not less than its distance from the opening.

3. Protection from falling debris.—Adequate provision must be made to afford protection from falling loads due to the collapse of any structure over an air-raid shelter or within a distance from such air-raid shelter equal to one-half the height of such structure, by the provision of a floor or by the strengthening of the existing floor where necessary or by a suitable roof or other construction based on an estimated static loading as representing the effect of impact, to the satisfaction of the Minister.

Provided that where such falling loads would not include heavy machinery, materials and goods of abnormal weight nor such constructions as chimney-shafts, towers, heavy colonnades, pediments or cornices but would comprise only the loads of a normal structure and superimposed loading of ordinary goods or light plant and equipment, it shall suffice if, for purposes of calculation, the falling loads be deemed to be static loads in accordance with the following requirements:

(*a*) For buildings wherein the loads are carried on load-bearing brickwork or stonework:

Number of Storeys at a Higher Level than the Top of the Shelter	Minimum Static Load (in Addition to the Floor Load) to Be Assumed to Represent the Effect of the Debris, Lb. per Square Foot of Floor Area
1 or 2	200
3 or 4	300
Over 4	400

(*b*) For buildings wherein the whole of the loads are carried on steel or reinforced concrete framing, the effect of the debris load may be assumed to be a static load of 200 lb. per sq. ft. of floor area (in addition to the floor load) irrespective of the number of storeys at a higher level than the top of the shelter.

For the purpose of this clause, the expression "floor load" means the combined dead and superimposed floor load calculated in accordance with the Ministry of Health Model Byelaws, Series IV—Buildings, 1939.

4. Stability.—All new constructions, extensions, additions and alterations in connection with air-raid shelter must be so executed that all loading occasioned thereby shall be safely sustained and transmitted to the ground without exceeding the limitations of the prescribed stresses except as herein provided for in respect of linings to trench shelters.

Except where executed in hard rock or other self-retaining materials, trench shelters must be provided with linings consisting of concrete, brickwork, steel (suitably protected from corrosion), or any other suitable material. Such linings must be designed and constructed in accordance with normal engineering principles in such manner as safely to retain the earth without exceeding the limitations of the prescribed stresses in the materials employed, or (in the case of any other material) such limitation of stresses as may be approved by the Minister.

Provided that where such trench shelter is at a distance from any building or structure of not less than one-half the height of such building or structure, the stresses in the materials employed in a lining of reinforced concrete or steel may exceed the prescribed stresses by not more than 25 per cent.

5. Gas-proofing.—Every air-raid shelter providing accommodation for more than twelve persons must be so constructed as to permit of its being rendered gas-proof without structural alteration should the need arise.

6. Space required in shelters.—The accommodation of an air-raid shelter must, subject to the ultimate limitations specified in paragraph 7, be determined in accordance with the following rules, that is to say:

(1) (*a*) in the case of a shelter accommodating not more than twelve persons, or (*b*) in the case of a trench shelter having openings at both ends into the open air, it must have for every person accommodated a floor area of not less than 3¾ square feet.

(2) In the case of a shelter other than as described in rule (1) above, not intended to be permanently sealed against gas, and ventilated by the entrance and exit or otherwise efficiently ventilated by natural means, or by mechanical means at a rate of not less than 150 cu. ft. of air per hour, per person, it must have, for every person accommodated,

not less than 6 square feet of floor area,
not less than 50 cubic feet capacity,
not less than 25 square feet of surface area of all walls backed by earth, other walls not less than 8½ in. thick, floor and ceiling or roof.

Provided that the floor area, capacity or internal surface area of any such shelter may be of less extent subject to the following conditions:

(*a*) That the shelter is ventilated mechanically at a substantially higher rate than the normal (exceeding 450 cubic feet of air per hour for every person in the shelter) and provided that satisfactory arrangements are made for emergency operation of the ventilating plant, when it will be sufficient if there is a floor area of 3¾ sq. ft. for every person in the shelter, or (*b*) that the shelter being entirely below ground level has abnormally massive construction with dividing walls not less than three feet thick and heavy slabs or vaulting over not less than three feet in thickness at any part inclusive of any solid filling, subject to authorisation of the Minister.

(3) In the case of an unventilated shelter accommodating more than twelve persons intended to be permanently sealed against gas during the whole period of occupation, it must have, for every person accommodated,

not less than 6 square feet of floor area,
not less than 50 cubic feet capacity,
not less than 75 square feet of surface area of all walls backed by earth, other walls not less than 8½ in. thick, floor and ceiling or roof.

For the purpose of computing the floor area, when there are seats beneath which the floor does not extend (as in a shelter in the form of a horizontal tube), the area of such seats may be deemed to be floor area.

Every trench shelter shall have a horizontal floor and a clear head-room, measured therefrom, of not less than 6 feet extending throughout the length of such shelter or of as much of its length as is intended to provide accommodation.

7. Limits of accommodation.—In order to minimise the number of casualties likely to result from a direct hit every shelter should, wherever the circumstances of the case make it possible, be divided into sections or compartments for the accommodation of not more than 50 persons.

Every trench shelter intended to accommodate more than 50 persons must be divided into sections. In the case of a continuous trench shelter such divisions must be effected by a change in direction through an angle of 80 to 100 degrees and extending in the new direction a distance of not less than 5 feet (measured clear of the width of the trench shelter) subject to such distance being not less than 25 feet in the case of a second change of direction involving a return parallel to and opposite the first section.

In the case of any other shelter intended to accommodate more than 200 persons, compartments must be formed by the erection of dividing walls extending the full height of the shelter. If such compartments accommodate not more than 50 persons each of the dividing walls must be of reinforced concrete not less than 12 inches thick or of sound brickwork or sound stonework not less than 13½ inches thick. New dividing walls must be constructed in brickwork in cement mortar.

If such compartment accommodate more than 50 persons the dividing walls must consist of either:

(*a*) a wall of reinforced concrete not less than 24 inches thick, or

(*b*) two walls, each consisting of reinforced concrete not less than 12 inches thick or of sound brickwork or sound stonework not less than 13½ inches thick, with a space between them not used as an air-raid shelter.

No compartment of a shelter may be used to accommodate more than 200 persons.

Temporary openings not exceeding 6 feet in width may be left in the dividing walls between compartment of shelters for peace-time convenience, subject to provision being made for the materials to fill such openings being permanently stored on the premises, and for the linking up of reinforcement in reinforced concrete.

8. Accessibility of air-raid shelter.—Every air-raid shelter must be boldly marked and so situated and accessible by day and by night that the persons for whose protection it is intended may pass from the place where they work into their shelter within 7 minutes.

In the case of A.R.P. personnel, including persons occupied with essential duties which may not be entirely discontinued during the whole period of a raid (such as boiler-house and switchgear attendants and men in charge of machinery which cannot be shut down at short notice), special provision must be made for the necessary air-raid shelter at, or adjacent to, their working positions.

9. Entrances and exits.—Every air-raid shelter and every compartment of an air-raid shelter must be provided with an entrance which (except in the case of an air-raid shelter intended to accommodate not more than 12 persons), shall have a width of not less than 2 ft. 6 in.

Every air-raid shelter intended to accommodate more than 12 persons must have at least two exits as remote as may be practicable from each other, one of which may be the normal entrance if suitable. One at least of such exits must, wherever practicable, give access to the open air and when possible be so situated as to be free from the danger of falling debris. Where the emergency exit gives access to another air-raid shelter or to another compartment of an air-raid shelter, the opening must not exceed 3 ft. 6 in. in height nor 2 ft. 9 in. in width.

Where the entrances to or exits from an air-raid shelter are in the wall of a building or are situated at a distance from any building or structure, not exceeding one-half the height of such building or structure, all reasonable measures must be taken to afford one of such entrances or exits proper protection from falling debris.

If an entrance or exit of an air-raid shelter be from or to the open air and be above the ground level, such entrance or exit must be protected by a door or screen affording a degree of lateral protection not inferior to that specified in paragraph 2 of this code and of such extent as to prevent the entrance of splinters.

10. Drainage.—Where necessary, adequate arrangement must be made to keep every air-raid shelter free from water.

11. Sanitary facilities.—Every air-raid shelter must have proper closet facilities at the rate of not less than one seat per 25 persons accommodated and also such subsidiary buckets and urinals as may be necessary. Such conveniences must, where practicable, be contiguous with the shelter and divided therefrom by a partition or partitions extending the whole height of the shelter.

Provided that where adequate sanitary facilities are afforded (by an existing building or otherwise) in close proximity to the shelter and within ready and easy access, this requirement may be deemed to be complied with.

12. Lighting.—Every air-raid shelter must be adequately lighted, and a system of independent lighting must be installed sufficient to afford such light as may be necessary in the event of the failure of the normal lighting service. Where generators or large storage batteries are employed for such purpose, they must be isolated and have separate ventilation.

Where electric torches or electric battery hand lamps are employed for such purpose, a sufficient supply must be permanently kept in the shelters.

13. Dangerous pipes, etc.—Pipes, tanks or containers which might prove a source of danger (such as pipes or containers conveying or holding steam, gas, compressed air, refrigerants or noxious chemicals) must not be permitted in any air-raid shelter, and water pipes connected direct to the mains or to large supply tanks, and gas pipes, must be provided with such valves as may be necessary to permit of their being isolated where they pass through any shelter.

Where water mains or sewers are of such size or in such proximity to an air-raid shelter as to be hazardous such provision must be made as may be necessary to exclude their contents from the shelter in the event of damage.

APPENDIX TO PART I

Rules for Hollow Types of Floor Construction Which May Be Deemed to Conform with the Requirements of Standard Overhead Protection

Hollow type construction which has been designed for its normal structural purpose in accordance with the Code of Practice for the use of Reinforced Concrete in Buildings prepared by the Reinforced Concrete Structures Committee of the Building Research Board, or in accordance with the various building regulations at present in force, and which is composed of

(*a*) a system of hollow tiles or hollow concrete blocks of good standard quality and of a maximum width of 12 in., embedded between reinforced concrete ribs of width not less than 2 in. or one-quarter of the width of the tiles of blocks, whichever is the greater, or

(*b*) a system of precast reinforced concrete structural units of a maximum width of 12 in., with or without supplementary ribs of reinforced concrete deposited in situ or supplementary steel in the joints between the units,

and which in each case (*a*) and (*b*) has, above the system of tiles, blocks or precast units not less than 3 in. of reinforced concrete, or alternatively not less than 2½ in. of reinforced concrete, together with a superimposed screening not less than 1 in. thick.

PART II

ADVICE AS TO INCIDENTAL MATTERS AND AS TO METHODS TO BE FOLLOWED IN PROVIDING SHELTERS

General—Layout of Shelters—Notes on the Ventilation of Shelters—Methods of Providing Shelters—Notes on Construction of Trench or Tunnel Shelters outside Buildings—Notes on the Construction of Shelters within Buildings—Construction of Emergency Exits from Shelters in Building—Provision of Shelters in a Typical Mill Building—Provision of Shelters in a Multi-storey Warehouse Building—Provision of Shelters in a Building with Basement and Area, Such as an Office Block—Provision of Shelters in a Shop, on Corner Site, with Basement Extending under the Pavement and with Pavement Lights.

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No. 5: "Structural Defence," 1st ed.
No. *5A*: "Bomb Resisting Shelters," 1st ed.
No. 6: "Air Raid Precautions in Factories and Business Premises," 1st ed.
No. 7: "Anti-Gas Precautions for Merchant Shipping," 2d ed.
No. 8: "The Duties of Air Raid Wardens," 2d ed.
No. 9: "Incendiary Bombs and Fire Precautions," 1st ed.
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No. 3: "Organisation of Decontamination Services," 2d ed.
No. 4: "Organisation of Air Raid Wardens' Service," 2d ed.
No. 5: "Anti-Gas Training," 2d ed.
No. 6: "Local Communications and Reporting of Air Raid Damage," 1st ed.
No. 7: "Personnel Requirements for Air Raid General and Fire Precautions Services and the Police Service," 1st ed.
No. 8: "The Air Raid Warning System," 1st ed.
No. 9: "Notes on Training and Exercises," 1st ed.
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INDEX

A

Action Warning message, 169
Aids, traffic, 187, 188
Air arm, 1, 10
Air attack, 1, 2, 4, 6, 7, 19, 20, 59, 69, 70, 77
  purpose, 59
Air bombardment, 13, 17, 18, 69
Air defense, 1, 66–69, 72
Air forces, 2, 3, 6, 9
Air lock, 152
Air power, 1, 2, 3, 5, 11, 58
Air Raid Precautions, Assistant Directors, 237–239, 249
  Chiefs of Services, 237–239
  clerks, 243
  command organization, 128, 235–237, 248
  communications, 235, 246, 247
  control, 236, 245
  controllers, 243
  depots, 252–254
  deputy director, 237
  director, 237, 238, 249
  dispatchers, 243
  division headquarters, 235, 239, 241
  division report center, 235, 241, 244
  factory plan, 261–265
  general headquarters, 235–239, 241
  local report center, 235, 241, 244
  main report center, 235, 240–242
  organization, 238, 241, 263, 264
  plans, 263
  plotters, 243, 244
  reports, 245, 246
Air raid shelters (*see* Shelters)
Air Raid Warden Service, 174, 251
Air raid wardens, 75, 83, 123, 128, 163, 174, 221
Air raid warnings, 247
Air raids, 9, 10
Air regenerator, 156
Air superiority, 1, 5, 11
Air warfare, 1, 2, 9, 12, 13, 17
Aircraft, fighting, 3, 9, 69, 70
Aircraft armament, 3, 18
Aircraft Intelligence system, 165
Aircraft Warning Service, 6, 67, 68, 75, 164, 165, 167, 168
Aircraft Warning system, 165, 168
Airdromes, 73, 74
Air-gas attack, 60, 61
Airlock, 150
Airplane performance, 9, 18
Alarms, air raid, 75, 147
  gas, 147, 148, 173
Altitude of bombing, 21, 22
Ambulance service, 198
Angle of fall, bombs, 21
  impact, 21
Antiaircraft artillery, 3, 6, 17, 70, 71
Antiaircraft defense, 70, 71
Anti-gas, cape, 144
  equipment, 128
  ointment, 146
  organization, 163
  precautions, 131, 134, 161
  protection, 61, 142, 143
  suit, 129, 130, 143–145
  treatment, 131, 146, 147
Areas, contaminated, 147, 157
  danger, 62–64
Armament of bombers, 3, 20
Armies, 5, 6
Arsenical smoke, 61
Attack, air, 1, 2, 4, 6, 7, 19
  air-gas, 5, 6, 10, 60–65, 75
Aviation, 12
  bombardment, 3, 69, 70
  power of, 12, 19
  pursuit, 3, 70

B

Ballistic characteristics, 20, 23
Ballistics of bombs, 20, 23
Balloon barrages, 6, 17, 71, 72
Barricades (shelters), 107, 108
Bibliography, 313

Blackouts, 7, 75, 185
Blanket doors, 151, 152, 153
Blast, bombs, 27, 33–35
  effect, 34, 35
  pressure, 34, 35
Bomb craters, 38–40
Bomb damage, 45
Bombardment, aviation, 3, 4, 69, 303
  of cities, 17, 18, 303
Bombers, 3, 69
Bombproofing, 302
Bombs, chemical, 46
  demolition, 23, 24, 32, 59, 77
  fragmentation, 23, 25, 37, 77
  gas, 3, 19, 46, 51–53, 62, 261
  general purpose, 23, 25, 32, 59, 77
  high explosive, 10, 18, 23, 53, 59, 60, 62, 260
  incendiary, 10, 18, 19, 46, 54–56, 59, 60, 62, 75, 114, 115–118, 121–123, 261
  maximum velocity, 22
  multiple unit, 56
  quantities of, 8
  sizes, 24, 51
Brisance, 27
Buildings, design and construction, 303
  multistory, 87, 97, 102, 104, 114, 115
  protection of, 75, 85, 111, 303

C

Call systems, fire and police, 247
Camouflage, 297, 298
Camouflet, 38
Cancel caution message, 170
Canister, gas mask, 137, 138
Cannon, light, 3
Capacity of shelters, 81, 92
Cape, anti-gas, 144
Casualties, 5, 9
Chemical bombs, 46
Chemical closets, 103
Chemical detectors, 133, 134
Chemical extinguishers, 120, 121
Chemical sprays, 3, 19
Choice of weapons, 58, 59
Cities, bombardment of, 17, 18
City planning, 303, 304
Civil Air Defense, measures, 290, 299, 304
Civil population, direct attack on, 1, 3, 5, 304
Cleansing center, gas, 130, 148, 160, 190, 227–229, 275
Clerical force, 198
Clerks, Air Raid Precautions, 243
Closets, chemical, 103
Clothing, decontamination, 160, 191, 230, 231
  protective, 76, 129, 130, 303
Codes, warning signal, 172
Collective protection, 129, 130, 147
Collective protectors, 155
Communication systems, 76, 207, 235
Concealment, 290, 296, 297
Conservative military viewpoint, 1
Contaminated areas, 147, 157
Control, Air Raid Precautions, 236, 245
Controllers, Air Raid Precautions, 243
Controlling incendiary bombs, 117–121
Costs of shelters, 89
Cover, 287–289
Crater dimensions, 38, 39
Cratering, effect, 27, 38
Craters, bomb, 38, 39, 40
Curtain, gas, 151–153

D

Damage, bomb, 45, 85, 221
Danger areas, bombs, 62–64
Darkness, 3, 4, 17
Deaths, 5, 6
Debris clearance, depots, 212
  divisions, 212
  falling, 85
  service, 211–213, 215, 244
  service organization, 211, 212
Decontamination, 130, 157, 276
  clothing, 160, 191, 230, 231
  depot, 223–225
  general, 148, 160
  organization, 223
  outside cities, 231
  of personnel, 160
  service, 222, 223, 225
  squads, 225, 226, 277
  vehicle depot, 229, 230
Decontaminators, 158
Defense, active, 6, 67–69, 72, 164
  air, 66, 67
  antiaircraft, 70, 71
  passive, 6–8, 65, 68, 73, 76, 83, 164, 222, 236

Defense, structural, 304
Demolition, bombs, 23, 24, 32, 77
  gangs, 219
  service, 217, 218
  service organization, 218
Department of Concealment, 300, 301
Department of Evacuation and Shelter, 300
Department of Lighting Control, 300, 301
Department of Public Instruction, 300, 301
Department of Structural Defense, 300, 301
Departments, wardens, 180–182
Depot, Air Raid Precautions, 252
  decontamination, 223–225
  first aid, 191, 192
  gas identification, 233
  gas mask, 185
Depth of destruction, 42
Deputy Director of Air Raid Precautions, 237, 238
Destruction, depth, 42
  radius, 42, 63
Destructive power (bombs), 27
Detection of gas, 131, 147, 148, 231
Detectors, chemical, 133
Direct air action, 1, 5, 11
Director of Air Raid Precautions, 237, 238
Director of Civil Air Defense, 74, 300, 301
Dispatchers, Air Raid Precautions, 243
Dispersion, 84, 97, 260, 277, 290, 294–296, 303
Dissemination of warnings, 165
Divisions, wardens, 181, 182
Doctrine of direct action, 5
Doctrines of war, 4
Domestic shelters, 106, 107
Doors, protection of, 112, 150–153, 283
Douhet, General Guiho, 1, 11
Douhet doctrine of war, 5, 11, 61
Drills, Air Raid Precautions, 253, 256
Dugout shelters, 86, 87, 91–93, 98

E

Education of public, 74, 127, 300, 301
Election bombs, 55, 56
Emergency fire fighting, 204, 205, 206, 272
Entrances to shelters, 82, 97
Equipment, anti-gas, 128
  fire fighting, 125
  gas identification, 234
  refuge rooms, 287
  wardens, 185
Establishments, protection of, 85, 103, 111, 259, 277
Evacuation, 7, 74, 79, 290, 291, 292, 293, 294
Exercises, Air Raid Precautions, 256
Exits to shelters, 103
Explosive factor, 26, 27
Explosives, classification, 26
  high, 26
  low, 26
External lights, 186
Extinguishers, chemical, 120, 121

F

Factor, explosive, 26, 27
Factories, bombardment of, 17
  new, 277
Factory, Air Raid Precautions plan, 261–267
  first aid, 274
  shelters, 269–271
  warning system, 266, 267
Federal Government, role, 7, 73
Fighters, aircraft, 69, 70
Fire combative measures, 201
Fire Department, 204
Fire fighting, 75, 123, 124, 203, 272, 273
Fire fighting, collective, 124
  individual, 123
  organization, 126
  personnel, 75, 83, 126, 203, 206, 207, 211
Fire lookouts, 200
Fire mobile patrols, 203, 205
Fire parties, 124, 125, 273
Fire precautions, domestic, 283, 285
  organization, 126, 199, 202
  service, 199
Fire preventive measures, 200
Fire service, rural, 209, 210
Fire stations, auxiliary, 204, 205
Fireplaces, 149, 150
Fireproofing, 305
First aid, depots, 191, 192
  parties, 191, 192
  posts, 191, 193–196, 274
  service, 75, 189, 190
  treatment, 7, 274
Flight, bomb, time of, 22
Flooding, precautions, 215, 216
  of shelters, 97, 216

Floors, protection of, 112
  strengthening of, 94
Flying fortress, 18
Fog, 3, 69
Food, anti-gas precautions, 161, 162
Fragmentation, 27, 36
Fragmentation bombs, 23, 25, 37, 77
Fragments, bombs, 36
  penetration, 36, 37
Frequencies of vibration, 34, 35
Fuller, General J. F. C., 64
Fuses, bomb, 27
  delay, 27
  instantaneous, 27

G

Galleries, shelter, 87–90
Garner, James W., 2
Gas, definition, 46
  detection of, 131, 132, 148, 231, 276
  lung injurant, 48, 132
  nonpersistent, 46
  persistent, 46, 52, 60–62, 157
  protection against, 75, 127–130
  removal of, 147, 156, 158–160
  tear, 48, 131
  use of, 5, 6, 10, 127
  vesicant, 48, 62, 132, 157, 158
Gas alarms, 147, 148, 173
Gas attacks, 5, 6, 10, 60–65, 75
Gas bombs, 3, 19, 46, 51–53, 62
Gas cleansing centers, 130, 148, 160, 190, 227–229, 275
Gas curtain, 151–153
Gas detection service, 231
Gas identification, 147, 148, 231
  depots, 233
  officers, 232, 233
  service, 231–233
Gas mask depot, 185
Gas masks, civilian, 129, 136, 137, 286, 303
  civilian duty, 76, 129, 138, 139
  general service, 129, 140, 141
  infants', 137, 139
Gas respiratory irritant, 49, 53, 132
Gas searchers, 276
Gas shelters, 93, 97, 147–150, 156
Gas signals, 173
Gas sprays, 53
Gas warfare, 60, 61
Gases, properties, 50
  war, 127, 134
Gas-proof shelters, 148, 149, 283
Gas-proofing, 97, 149, 283, 305
General purpose bombs, 23, 25, 32, 77
Geneva Disarmament Conference, 15
German War Book, 4
Groups, wardens, 179–182
Groves, General P. R. C., 16, 72
Guns, antiaircraft, 70, 71

H

Hague, rules of warfare, 13–15, 17
Hague Commission, 13, 14, 16
Hague Conference, 12, 16
Haldane, J. B. S., 89, 104
High explosive bombs, 10, 18, 23, 44, 53, 59, 60, 62
High explosives, 26
Higher Civil Air Defense, 299, 300
Home protection, 279, 280
Hose, fire, 206
Hospitals, base, 191, 197
  clearing, 191, 196, 197
Hydrolysis of gas, 47

I

Identification service, gas, 76, 231–233
Impact of bombs, 27, 28
Impact velocity of bombs, 22
Incendiary agents, 56, 57, 62
Incendiary bombs, 10, 18, 19, 46, 54–56, 59, 60, 62, 75, 114, 115, 116, 117, 118, 121, 122, 123, 261
Index, bomb, 39
Individual protection, 128, 131
Indoor shelters, 86, 87, 95, 101–103
Infant's gas mask, 137, 139
Inflammable liquids, 273
Information centers, 166
Inspections, Air Raid Precautions depots, 253
Instruction, public, 74
Instruments, warning, 171, 172
Intelligence System, Air Warning Service, 165
Intercept airplanes, 69, 70
Isolation of damage, 85

K

Key workers, 265

L

Lachrymatory gas, 53
Land warfare, 66
League of Nations Assembly, 15
Lewisite, 47, 132
Lighting, internal, 186
  of obstructions, 193
  of shelters, 97
  restrictions, 185, 267, 285
  traffic, 187
Lights, concealment, 267
  control of, 83, 304
  external, 186
  extinction of, 7
  indoor shading, 187
  pilot, 268
Local authorities, 74
Local government, role, 73
Lookouts, 266
Lung injurant, gas, 47, 132

M

Machine guns, 3
Marking areas, 147, 157
Marking roads, 268
Masks, gas (*see* Gas masks)
Mean range error, 22
Means of air attack, 20
Medical service, 75, 189, 190
Message, action warning, 169, 170
  Air Raid Precautions, 243
  cancel caution, 169–171
  preliminary caution, 169, 170
  raiders passed, 170, 171
Methods of protection, 78, 113
Military objectives, 2, 12–14, 16, 58
  identification, 2, 17
Military targets, 14
Mining, 27, 41
Mining effect of bombs, 27, 41
Morale, maintenance of, 79
Multiple-unit bombs, 56, 122
Multistory buildings, 87, 102, 104
Munitions industry, 17
Munitions workers, 12
Mustard gas, 46, 47, 132

N

Naval warfare, 66
Navy, 6
Neutralization of vesicants, 158
Nonpersistent gas (*See* Gas, nonpersistent)

O

Objectives, military, 2, 12–14, 16, 58
Obstructions, street, 188
Organization, for civil air defense, 300
  fire, 126
  for passive defense, 74
Outdoor shelter, 86, 87, 97
    (*See also* Shelters, outdoor)

P

Parties, fire, 124, 125, 273
Passive defense, 6–8, 65, 68, 73, 74, 76, 83, 236
  responsibility for, 7
  workers, 84
Penetration, by bombs, 27, 29, 30–33, 84
  of buildings, 33
  depths of, 30–32
  of fragments, 36, 37
Persistent gas, 46, 60
Petroleum, 122
Petry's formula, 30
Philosophy of battle, 4
Phosgene, 61
Phosphorus, 57
Physicians, 83
Physiological effects, 47
Planning, future, 290, 302
Plans, passive defense, 82–85
Policy, protection, 84
Posts, wardens, 187
Potassium, 57, 123
Power, destructive, 27
Precautions, anti-gas, 131, 134, 135
  against incendiary bombs, 116
Preliminary caution message, 169, 170
Pressure, blast, 34
  static equivalent, 34
Private residences, 76, 103
Protection, anti-gas (buildings), 149
  of the body, 131, 142, 143
  of buildings, 75, 85, 111, 271
  collective, 129, 130, 147
  degrees, 78
  of essential activities, 78
  of eyes and lungs, 131, 135
  of food, 148

Protection, against gas, 75, 127–130
  general, 84
  of the home, 279, 280
  against incendiary bombs, 114–121
  individual, 128, 131
  industrial establishments, 103, 111, 126, 259
  lateral, 97
  of machinery, 271
  measures, 74–76
  methods, 78, 113
  objectives, 78
  overhead, 96
  of personnel, 84, 86, 88, 277
  plans, 260
  policy on, 84
  principles of, 115, 116
  of roofs and floors, 112
  standards of, 95, 96
  of utilities, 85
  of vital establishments, 85, 111
  of walls, 111, 113
  of water, 148
  of windows and doors, 105, 112, 151–153
  of workers, 268
Protective clothing, 76, 129, 130, 303
Protectors, collective, 155
Public education, 74, 127, 300, 301
Public warning signals, 170, 171
Pursuit airplanes, 69, 70

R

Radio communication, 247
Radius, of destruction, 42
  rupture, 42, 43
Raiders Passed message, 169, 170
Range of bombs, 20
Range error, mean, 22
Recreation, Air Raid Precautions workers, 253
Refuge rooms, 87, 104–106, 149, 150, 280, 282–284
  equipment, 287
  gas-proofing, 283
Refugees, care of, 290, 298, 299
Removal of gas, 147, 156
Repair, depots, 219
  gangs, 219, 220, 274
  service, 217, 218
    organization, 218
Report centers, Air Raid Precautions, 244
Rescue service, 211, 212
Rescue squads, 212–215, 273
Rescue work, factory, 273
Respiratory irritant gas, 48, 53, 132
Roofs, protection of, 112
Rules of air warfare, 13–16
Rupture, radius of, 42, 43
  effect, 27
Rural warning signals, 173

S

Safe depths, 88
Sand method of control, 118
Sanitation in shelters, 98
Searchers, gas, 276
Searchlights, 67, 69
Sector information center, Aircraft Warning Service, 166
Segregation, 290, 303
Self-cleansing, methods, 131, 146
Shelters, Anderson, 281
  barricades, 107, 108
  capacity, 92
  cellars and vaults, 94, 95
  classes of, 86
  communal, 86
  conical towers, 100, 101
  domestic, 87, 280, 281
    surface, 87, 106, 107, 280, 281
  dugout, 86, 87, 91–93, 98, 280
  entrances, 82
  exits, 103
  factory, 269–271
  flooding, 97
  form of, 85
  gas-proof, 93, 97, 147–150, 156
  household, 280
  indoor, 86, 87, 95, 101–103
  industrial, 86
  lighting of, 97
  multistory buildings, 87, 102
  outdoor, 86, 87, 97
  preparation of, 110, 111
  private, 86
  public, 81, 86
  refuge rooms, 87
  selection of, 109
  semisurface, 280, 281
  subterred, 86, 93
  subways, 87, 90, 91
  surface, 86

Shelters, tools for, 98
  trenches, 98–100
  tunnels and galleries, 87, 89, 90
  types of, 87
  unventilated, 153, 154
  ventilated, 153, 154
  ventilation, 97
  water supply, 97
Shutters, window, 151
Silent approach, 3, 4, 34, 69
Sirens, warning, 171
Sizes of bombs, 24, 51
Skylights, obscuring, 268
Smoke, 3
Sodium, 57, 123
Spaight, Dr. J. M., 15
Spare parts, 85, 221
Sprays, gas, 3, 19, 53
Squads, decontamination, 225–277
Standards of construction, 278
  protection, 96, 97
State government, role, 73
Stores and supplies, 85
Streets, damaged, 221
Structural defense, 302
Subterment, 87, 88
Subways, shelter, 87, 90, 91
Suit, anti-gas, 129, 130, 143–145
Surprise attacks, 4

T

Tear gas, 48, 131
Technique of silent approach, 3, 4, 34, 69
Telephones, public, 246
Thermite, 57
Thermite bombs, 54
Time of flight, bombs, 22
Tools for shelters, 98
Towers, conical, 100, 101
Traffic, aids, 187
  lights, 187, 188
  signs, 188
Training, Air Raid Precautions, advanced, 250, 255
    basic, 250, 255
    combined, 250, 256
    Drills, 253, 256
    Exercises, 256
    General, 249, 261
    Higher, 250, 257
    individual, 250, 255
Training, Air Raid Precautions, in industry, 258
    part time, 251
    personnel, 258
    plan, 250, 251
    program, 251, 252
    recreation, 253
    refresher, 258
    schedules, 253, 254
    team, 250, 255
Training fire fighters, 206
Training Gas Identification Officers, 234
Training wardens, 183, 184
Trajectory of bombs, 20
Travel to shelter, 81
Treatment, anti-gas, 131, 146, 147
Trenches, shelter, 98–100
Tunnels, shelter, 87–91

U

Utilities, protection of, 79, 268, 274

V

Vaults, shelter, 87, 94, 95
Vehicle, decontamination depot, 229, 230
Velocity, impact, of bombs, 22
  maximum, of bombs, 22
Ventilation of shelters, 97, 155, 156
Vertical speed of bombs, 20
Vesicant gas, 48, 132, 142, 143, 146, 147, 157, 158
Vibration frequencies, 34, 35
Vital establishments, protection, 7

W

Walls, protection of, 111, 113
Wardens, air raid, 75, 83, 123, 128, 163, 174
  assistants, 178, 180–183
  associate, 178, 180–182
  departments, 180
  districts, 177–179
  divisions, 180
  duties, 175, 176
  factory system, 266, 267
  groups, 179–182
  higher organization, 180
  organization, 176, 181
  posts, 177–182, 185, 254

Wardens, rural, 183
  sectors, 177–180
  special, 178
  training, 183, 184
  zones, 180, 182
Warning, 7, 128
  dissemination, 165
  districts, 168
  instruments, 171, 172
  length of, 80
  list, 168
  messages, 169
  signals, public, 170, 171
    rural, 173
Water, anti-gas precautions, 161, 162
  method control, 118, 119, 120
Water, supplies, 97, 208, 209, 273
Weapons, air warfare, 2, 3, 5
  choice of, 58, 59
Weather, influence of, 47
Windows, protection of, 105, 112, 151, 283
  darkening of, 186

Z

Zone Information Centers, 166
Zones, A.W.S., 165, 166

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